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Changing territories, spatial planning, land management and environmental threats: Agro-energy districts as chances for sustainable development

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For this thesis, I thank all the professors and researchers with whom I have worked in these years, leading me to acquire innovative knowledge and research.

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Changing territories, Territorial planning, land management and environmental threats. Agro-energy districts as chances for sustainable development

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1. Introduction

The research activity carried out in this PhD thesis focused on the analysis of different contexts of Mediterranean Europe. The case studies were chosen since they are almost similar and comparable, nonetheless they have place-specific divergent characteristics (Chorianopoulos et al., 2010), linked to their history, culture, society and economy. The metropolitan area of Rome and the province of Viterbo are among the main case studies.

The research project was developed on various aspects, describing them with key word. The first key word is "changing territories" since contemporary contexts are increasingly complex and constantly changing due to processes of various nature (social, economic, cultural) that operate on the landscape and the regional system (Catalàn et al., 2008; Grigoriadis and Salvati, 2015; Maloutas, 2004; Salvati and Gargiulo Morelli, 2014). Given this background, the concept of "territorial planning" emerges because adequate planning must make use of appropriate tools, effective strategies and appropriate plans to ensure proper land management and develop it in a sustainable manner (Masera et al., 2006; Colantoni et al., 2016). Furthermore, the concept of "land management" reflects the emergence of being able to better manage local and regional contexts in view of "environmental threats", resulting from processes of soil degradation, desertification, soil quality, soil sealing, climate change, loss of ecosystems and the progressive depletion of fossil resources (Salvati and Bajocco, 2011; Munafò et al., 2010). In this perspective, the work has focused on the possibility of enhancing and promoting local contexts in order to identify them as "agro-energy districts as chances for sustainable development", strengthening especially the primary sector.

The conversion of agricultural areas into agro-energy districts represents a significant socio-economic opportunity for agricultural diversification, sources of supply and reduction of polluting emissions, helping to mitigate climate change and increase the energy autonomy of territories. The results obtained derive from a territorial analysis through spatial technologies (GIS), statistical and economic elaborations, highlighting advantages and disadvantages to implement such a project. In fact, in addition to the three dimensions of sustainability (economic, social and environmental), energy has been identified as a fourth essential component to distinguish resilient and sustainable systems, starting realities based on circular economy. Particularly, peri-urban and rural areas in recent decades have seen a significant loss of population and employment, but also an increase in abandoned areas (Gkartzios and Scott, 2015; Goldstein and Kluge, 2016; Milbourne, 2007).

The research activity has benefited from the collaboration of several European universities (e.g. Universitat de Valencia) and national and research institutions, such as CREA (Council for Agricultural Research and analysis of the agricultural Economy), which co-financed the research project. The overall study aims to propose original approaches to provide innovative tools to manage and propose sustainable development scenarios in urban and rural contexts. The results have been presented at conferences and seminars and published in international scientific journals, often indexed.

Several issues were addressed in the PhD research period. In this thesis, each chapter discusses different issues that were carried out during the doctoral program. The chapter "Recent territorial configuration between demographic, socio-economic and landscape changes" deals with the recent processes and transformations that have specifically taken place in Southern Europe. Very often these changes are related to demographic and social dynamics, e.g. changing lifestyles, evolving

economic sectors, periods of economic development and recession. All these variations have consequences that finally affect the landscape of each analyzed territory. The work began with a work dealing with sprawl processes in specific Mediterranean contexts (Barcelona, Istanbul, Naples). Analyzing the different degrees of urban sprawl in European cities, the importance of understanding urban changes as a requirement for the design of procedures against sprawl. Urban sprawl was extensively studied in this PhD period as phenomenon since monitoring land-use/land changes aims at providing useful information for urban planners and policy makers for the management of unrestrained urban development and sprawl (Anderlini, 2003; Karaman, 2008).

Secondly, the comparison of three regions, e.g. metropolitan regions of Barcelona (Spain), Rome (Italy), and Athens (Greece), was studied. These regions share similar territorial characters, viewing an exclusive urban structure and socioeconomic conformation. However, sprawl has adapted to these contexts in different ways dependent on historical, cultural and political questions (Krumholz, 1992; Salvati and De Rosa, 2014). Sprawl is mainly related to (i) changes in the use of land destined for low-density residential settlements, (ii) changes in urban lifestyles towards social homogenization; (iii) a moderate loss of economic attractiveness of inner cities partly counterbalanced with a gaining importance of sub-centers (Catalàn et al., 2008; Chorianopoulos et al., 2010; Munafò et al., 2010). Showing a regional or national capital role, these cities have also hosted competitive events of global importance, such as in the case of Athens and Barcelona with the Olympic Games. By integrating their sprawl processes, the study provided an interpretation of the main socioeconomic drivers of change in contemporary Mediterranean cities.

Changes in land-use and landscape were then discussed in the following sub-chapters. For example, urbanization processes e.g. sprawl are analyzed in Tuscia (Italy), which is an Italian territory where urban and rural areas coexist in a traditional landscape among hills and mountains. Tuscia represent a treasure trove of great natural and agricultural value, regardless of whether the dispersive dynamics have also occurred there. Its social and economic components appeared a limit to sprawl processes, allowing to preserve its rural identity and the relative environmental landscape.

While there are some areas that have managed to remain natural and with soils of high quality over time, unfortunately many realities, especially urban and peri-urban without effective planning tools and have registered a high consumption of land. Particularly, urbanization processes can be traced by means of a novel index (VHG - 'Vertical-to-Horizontal Growth' ratio), which was proposed discriminating long-term vertical from horizontal urban expansion. Based on this index, changes in vertical and horizontal profile of settlements at regional and local scale were analyzed in Greece, a country experiencing particularly complex urban cycles in the last century (Salvati, 2016), and, more specifically, in the metropolitan region of Athens (Colantoni et al., 2016), at 12-time intervals covering one century between the 1910s and the 2010s. The statistics elaborated are characterized by high cross-country comparability, regularity in data updating, standardization in survey techniques, and spatial detail.

In addition to these complex contexts, there is also a high degree of diversity in the urban environment. Barcelona, Rome and Athens have undergone scattered urban patterns as a result of differentiated development processes (Di Feliciantonio and Salvati, 2014). Shannon diversity (H') and Pielou's evenness (J) indexes were used to assess the diversification in the degree of land imperviousness at the local scale. These indexes reflect the stratification of different intensities of

land imperviousness as a result of a mixed distribution of land-uses typical of cities with advanced and diversified functions. The highest values of these indexes are associated to central cities and polycentric sub-centers hosting dense population, upper economic functions and typical socio-spatial patterns. Transitional sprawling areas are hypothesized to share intermediate evenness values between urban and rural areas.

Even in Italy, urban sprawl represents a peculiar constituent of vast areas, where it has removed the distinction between cities and countryside, leading to high socioeconomic and environmental costs. Two kinds of urban growth exhibit very different soil consumption rates and characteristics: (i) urban growth involves almost total saturation and natural soil sealing; conversely, (ii) a dispersed city is characterized by the coexistence of buildings and green areas, which guarantees a partial persistence of natural features. These two categories also differ in the degree of fragmentation that they exert outside the strictly urban areas. While impacts on peripheral fringe areas due to "compact" urban extensions are relatively small, in the case of sprawl, a substantial part of the urban margin is taken away from the original use due to fragmentation (Duany et al., 2000; Terzi and Bolen 2009; Frondoni et al., 2011; Munafò et al., 2011).

Specifically, 94 out of 121 municipalities belonging to Rome's province were explored. The work focused on an integrated research framework based on the use of high-resolution digital maps of planned and actual land-use with the aim to verify if deregulated urban expansion led to a progressive expansion of discontinuous settlements. Evaluating the contributing role of spatial planning to discontinuous urban expansion constitutes a knowledge base for effective land management strategies targeting soil conservation, urban containment and sustainable development of cities. Rome's expansion has reflected a combination of planning decisions and informal practices leading to interrelated (and sometimes uncontrolled) urban transformations (Maloutas 2004; Arbaci 2007; Arbaci and Malheiros 2010), as well as in other Mediterranean cities, such as Athens and Barcelona (Costa et al., 1991; Archibugi 2004; Giannakourou 2005; Chorianopoulos et al., 2010).

The investigative comparisons also included other contexts. Lisbon (Portugal), Barcelona (Spain), Rome (Italy), and Athens (Greece) were explored with an original approach to a joint structural and functional landscape analysis, introducing a new class of landscape metrics assessing basic features of patch perimeters. Specific computation on patch perimeters was carried out on fine-grained land-use maps covering homogeneously the European continent with the aim to characterize spatial patterns of neighbor patches, demonstrating contact points and perimeter length among two (or more) land-use types. A comprehensive set of class- and landscape metrics were derived. This approach appears complementary to classical landscape metrics and proved to be particularly useful to characterize complex, fragmented landscapes profiling metropolitan regions based on integrated evaluations of their structural (landscape) and functional (land-use) configuration. Spatial diversity was evaluated using the Shannon index applied to the composition of landscape bordering each patch.

Always considering the metropolitan regions of Barcelona (Spain), Rome (Italy), and Athens (Greece), another work carried out during the PhD investigates shifts from mono-centric structures towards polycentric spatial configurations in originally compact and dense metropolitan regions. Therefore, a simplified procedure was introduced that identifies population sub-centers and

evaluates spatial patterns of population growth—as a proxy of urban growth—over a relatively long time period. This procedure is based on a spatially-explicit analysis of the standardized residuals from a linear (ordinary least square) model that assesses the relationship between population density and the distance from a central location for each investigated region, under the hypotheses that (i) a mono-centric spatial structure is characterized by a perfectly linear relationship between the two variables and that (ii) population sub-centers—considered early signals of polycentric structures—are characterized by high and positive regression residuals. The proposed approach fixes a dynamic threshold for standardized residuals with the aim to identify and profile candidate sub-central locations.

Focusing then in Greece and Attica region, another research work had the hypothesis of verifying if the impact of 2007 recession on short-term demographic dynamics has been neutral compared with background, long-term trends. Greece, one of the European countries most affected by 2007 economic crisis (Goldstein et al., 2013; Simou et al., 2013; Goldstein and Kluge 2016), was selected as a representative context for studying the influence of economic cycles on both long- and short-term changes in population dynamics (Gkartzios and Scott, 2015; Grigoriadis and Salvati, 2015; Remoundou et al., 2015). Basic indicators were used to identify similarities and differences in demographic trends before and during the 2007 crisis, comparing regional-scale dynamics for the whole of Greece and Attica, the densest metropolitan region hosting Athens, the Greek capital.

Among the Mediterranean region in Europe, Catalonia region was considered as exemplificative case. Under the hypothesis that an exploratory analysis of a large set of contextual variables may provide the necessary basis for realistic predictions of future urban growth in spatially-heterogeneous regions (Salvati and Carlucci, 2014), indicators of land zoning derived from all the Municipal Master Plans in Catalonia region were used to analyze recent urbanization patterns and processes and to formulate local-scale scenarios of urban growth, taking into account differentiated socioeconomic contexts underlying planning decisions. By assessing the relevance of physical, environmental, and socioeconomic constraints to urban expansion, the work done contributes to design of urban growth models that incorporate the effect of planning decisions and place-specific land management policies that will contain urban expansion and promote a spatially balanced development.

The chapter "Evolving threats to the agricultural sector and the peri-urban landscape" instead, explores rural and peri-urban contexts, which have been the place of numerous invasive processes in recent decades. A specific analysis of urban expansion in the metropolitan region of Attica in Greece, exploring socioeconomic drivers of urban transformation and environmental implications of settlement sprawl, was provided. Especially, a special regard was devoted to the notion of land-use efficiency. In fact, the work is intended to provide a specific contribution on dispersed urban expansion, shedding further light on latent transformations of Mediterranean cities, progressively abandoning a compact urbanization and moving toward discontinuous metropolitan spatial structures. As known, the urban development of Attica has been characterized by episodes of illegal urbanization followed by legalization acts. By legally accepting informal buildings, the Greek government has powered the characteristic un-planned spontaneous development in several Mediterranean cities. Urban plans in Attica have acted more as general "guidelines" rather than

effective legal tools (Economidou, 1993). Urban informality takes benefit of incompetent planning systems to transform peri-urban landscapes.

A comprehensive analysis of cropland distribution was proposed over space in a Mediterranean European region (Athens, Greece) from 1960 to 2010. By adopting a multivariate strategy to analyze multi-domain indicators of urban expansion, the study identifies clustering or scattering patterns in the spatial distribution of cropland, and the most relevant factors involved in such trends, as a contribution to sustainable land management in expanding metropolitan regions of advanced countries.

Changing contexts of analysis, long-term dynamics of peri-urban agriculture *vis à vis* urban expansion (1988-2010) were analyzed in Toulouse, the fourth city in France, using two complementary research approaches. Under the hypothesis that socioeconomic attributes are relevant to identify land-use conflicts characterizing peri-urbanization processes, the first approach adopted is eminently quantitative and evaluates together environmental, economic and social indicators outlining agricultural systems, linking different types of urban development to (evolving) peri-urban farms (Salvati et al., 2016). The second approach builds on a qualitative review on a sample of farms with the aim to investigate farming evolution strategies and the implications for peri-urban land-use (Inwood and Sharp, 2012).

Identifying processes of urban growth and changes in peri-urban landscapes can reveal relevant findings. The landscape dominated by olive groves, compared to urbanization processes, offered new insights in sustainable land management strategies adapted to evolving metropolitan contexts. The Athens' metropolitan area was also investigated in another study, focusing on fallow landscape. Fallow land dynamics over a relatively long time period characterized by different subsidies' regimes-together with basic information on total cropland increase or decline-was considered a useful indicator to infer latent transformations in peri-urban landscapes and to propose strategies that may promote peri-urban agriculture and/or preserve relict cropping systems. While being largely influenced by the related subsidies' regime, fallow land is considered an element of peri-urban landscapes possibly associated with specific characteristics of the regional economic structure and the local community. In such contexts, the hypothesis was that fallow land increased in size over the study period together with direct payments to farmers (EU subsidies), declining more or less rapidly in the most recent transitional phase of rural development, with subsidies oriented mostly to fulfil environmental targets. The work added to this assumption hypothesizing that fallow land is (i) an additional stock of economic value (depending on the intensity of land speculation and the flexibility of regional planning systems, allowing-or preventing-change in zoning rules that authorize conversion to urban use), or (ii) a stock of rural land immediately available for crop intensification. Investigating regional-scale cropland dynamics and long-term trends in fallow land area in a peri-urban landscape dominated by traditional crops-mainly olive-and progressively threatened by urban sprawl, a spatially-explicit analysis of the distribution of fallow land at municipal scale complemented this work, analyzing the background socioeconomic context at the same spatial scale as a possible factor of landscape change.

Another research work done identifies (and discuss the role of) on multiple drivers of latent transformation in socioeconomic local systems, based on inherent conflicts with expanding urban regions. The approach proposed was aimed at verifying if landscape composition, structure and

diversity significantly changed along the urban gradient during the investigated period. Intuitive and counter-intuitive changes in the rural landscape of Greece included: (i) a spatially-homogeneous and continuous decrease of cropland; (ii) decreasing surface areas (e.g. arable land, horticulture and vineyards); (iii) a parallel growth of tree crops, especially olive; a (iv) spatially-heterogeneous decrease of fallow land concentrated in metropolitan and tourism districts, especially in the last decade characterized by economic crisis; and (v) an increasingly diversified landscape in accessible areas with intermediate population density and close to the sea coast.

At the end of this chapter, a comprehensive outline of the rapidly-evolving socioeconomic conditions were provided in Athens, the capital of Greece, over different time intervals in recent urban history (Milbourne, 2007). Notions such as 'rurality' and 'rural development' can be discussed within a new framework considering together urban sprawl, counter-urbanization and rural migration processes (Benson and O'reilly, 2009); in this regard, residential mobility is intimately related with specific socioeconomic attributes in turn shaping counter-urbanization, increasingly seen as an ideological and political issue (Gkartzios and Scott, 2015; Murdoch et al., 2003).

The chapter "Environmental Threats and Soil Consumption" highlights how recent phenomena that negatively impact on the environmental sphere are a challenge for today's society, including the importance of the police makers in offering reliable plans, strategies and actions. Some important definitions are given that attend to contextualize environmental processes that compromise soil quality and consequent risk of degradation, erosion and desertification processes. Building-up adequate methodologies to assess the relationship between environmental, economic and social factors is recognized as a difficult task due to the heterogeneity of cause-effects relationships and the linkage between LD and human activities. A discussion of some important aspects of LD contributes to the design of policies for the sustainable development of the Mediterranean region was provided.

Regarding these current environmental challenges, the doctorate has strongly emphasized the importance of analyzing the territories that are at risk. Mainly 155 metropolitan regions in six European areas (Western, Atlantic, Northern, Central, Eastern and Southern macro-regions) were explored. The work investigates spatial patterns of land consumption across Europe profiling cities according to background variables with the final objective to identify socioeconomic and territorial factors underlying recent sprawl processes at both city and regional level (Salvati and Gargiulo Morelli, 2014). Investigating the characteristic socioeconomic contexts more associated to a high rate of land consumption contributes to design of effective strategies of urban containment adapting to different urban typologies.

Nevertheless, the most investigated case study was the southern Europe and, particularly, Italy. An in-depth investigation of changes in biophysical and socioeconomic conditions of the Italian agricultural districts over time was proposed. Despite all European countries offer typical agricultural productions, the majority high-quality products are found in Mediterranean countries (Jongman, 2002). The aim was assessed local-scale spatial diversification in the degree of land susceptibility to degradation, taken as a proxy of desertification risk. Mediterranean rural areas are characterized by an apparent diversity in rural systems (Salvati and Bajocco, 2011). Socioeconomic transformations, due to processes of landscape, may reflect in a higher level of homogeneity or

heterogeneity in the level of land sensitivity to degradation, representing a possible threat to biodiversity resources (Jongman, 2002).

Always focusing on the Mediterranean basin of Europe, 66 metropolitan areas from 5 southern European countries (Portugal, Spain, France, Italy and Greece) were examined. The study provides an original analysis of the impact socioeconomic local contexts have on environmentally-fragile peri-urban regions in Mediterranean Europe. Land take and the characteristics of recently developed soils were evaluated distinguishing among compact, dispersed and mixed urbanization patterns with the use of high-resolution land-use maps. A comprehensive analysis of soil quality was founded on a compound index mixing different soil attributes with the aim to assess the overall depletion in soil resources due to urbanization (Salvati et al., 2014). The methodology proposed can be part of a geographic information system for regional planning and supporting decisions for a sustainable land-use management.

The chapter ends with a study on early forest fires that occurred in Lazio region, particularly in the province of Viterbo, specifying for each province, from which place and in what number is the distinguishing fires originate in different territorial categories by referring to the period 2003 to 2012. The issue of fires has been intensively addressed during my candidate visiting PhD period in Valencia, relating recent fires to climate change, increasing processes of soil degradation and therefore the need to manage a region (or specific areas) by anticipating risks of fires (Figure 1.1.).

Figure 1.1. Own photo taken in August 2018 in a forest area burnt (20 days after the fire).

The chapter "Smart contexts Towards Sustainability" introduces the shared objective of ensuring local sustainable development. The importance of analyzing and comparing contexts is fundamental aimed at sustainable development, supported by smart systems, e.g. the new technologies, which can guarantee the monitoring and analysis of socioeconomic and environmental conditions. This chapter deals with the concept of circular economy. The Italian contexts were analyzed reflecting on renewable energy, in order to offer concrete strategies for sustainability. Starting from their local intrinsic characteristics, potential opportunities and useful actions were suggested to increase their smart degree, without focusing only to urban areas but also enhancing their agricultural vocation. The setting up of agro-energy districts can be a reliable solution for increasing employment, enabling greater energy self-sufficiency, additional protection of traditional

rural landscapes and the rise of a circular economy which aims to re-use agricultural waste. Cities can make more pioneering, self-sufficient and sustainable their realities, in addition to earning positions in the ranking of smart cities through targeted policies and actions.

The chapter "Exploring contemporary context with GIS technologies" starts considering greenhouses as spatial landmarks. They are used to guarantee the economic system, i.e. a continuous seasonality of certain agricultural products. However, they occupy the soil, waterproofing it. In Spain and the Netherlands, greenhouses occupy a large part of agricultural land. Using soil sealing maps, an area occupied by greenhouses results as a large city. In this respect, offering opportunities for sustainability is crucial. The study gives new research inputs and actionable progress actions based on virtuous projects that have already combined greenhouses and energy from renewable sources. Greenhouse plants can be considered a local landmark that indicates where advantages and disadvantages coexist in a specific area. Though, the study of greenhouse plants (as economic and local landscape indicator) is already immature in Italy. Furthermore, nothing has been done to evaluate photovoltaic (PV) greenhouse plants as a part of the agricultural landscape with a potential energy, due to restricted database and very local research studies (e.g. Sgroi et al., 2014; Tudisca et al., 2013).

Rural contexts have been strongly analyzed. The study proposed was supported by positioning systems, as Global Positioning System (GPS) and Global Navigation Satellite System (GNSS), which can continuously record both the in-field and the correct position of a vehicle in use (Neményi et al., 2003) and GIS system. Measuring the effective distribution of such systems in less-favored areas, the work was developed from a project carried out under the rural development program (RDP) in the Lazio Region 2007/2013 measure 1.2.4.

In addition, rural areas are often affected by accidents at work. In this sense, GIS technologies make it possible to identify where accidents occur, also relating to the type of chance, consequences and worker involved. Quantifying job accidents is usually performed using classical methods and checklists (Marucci et al., 2013; Monarca et al., 2011), trying to register the most relevant information from each event, with the purpose to classify and comprehend which factors cooperate. For instance, the spatial location where agricultural, forestry, garden maintenance and hobby activities occurred may sketch numerous independent factors and drivers, which shape the overall exposure of a standard working operator and can even differ within different operators (Cividino, 2014; Marucci et al., 2013; Monarca et al., 2008, 2011, 2012; Bailer et al., 1997). A useful information on chance allows a better comprehension of the intimate relationship among risk perception of farmers and the key risks to which they are exposed (Jacinto et al., 2009). Considering another work carried out during the PhD, professional accidents occurred were detected in the last 6 years (2012-2017) in the primary sector, considering Italian administrative provinces as the elementary analysis' spatial domain. The study aims to identify where the major accidents occur, exploring in all their components (e.g. age of operator, working conditions, means used), supported by the database provided by the INAIL (National Institute for Accident Insurance at Work).

Finally, the thesis focuses on the main context of study of the PhD research activity, which is developed in the chapter "Identifying, planning and designing agro-energy districts". The European Community has extensively encouraged the inclusion of significant shares of energy produced from renewable sources in national and regional energy balances. The current energy guidelines required

encourage the use of renewable resources more than traditional fossil fuels (Colantoni et al., 2016). By supporting sustainable development, energy needs can be met by transforming agroforestry biomass into biofuel. From the standpoint of eco-systemic and energy sustainability, the calculation of how much biomass a territory can offer is relevant for elaborating future strategies and possibilities (Masera et al., 2006; Emer et al., 2011; Colantoni et al., 2016).

In European countries such as Italy, the awareness of the role of bioenergy was reached only at the end of the 1990s, after the Rio Conference on Climate Change in 1990 and the Kyoto Protocol in 1997. In the "National Renewable Energy Program for Biomass" (1998), the integrated approach to energy issues took on importance to (i) preserve the environment; (ii) improve the efficiency of energy sources; (iii) avoid waste; (iv) reduce the use of fossil fuels; and (v) rationalize the use of resources through the agreement between Public Administration and stakeholders in carrying out sectoral and territorial actions. Through the implementation tool "National Program for the Valorization of Agricultural and Forestry Biomasses" (1999), the actions focused on the sustainable development of agro-energy supply chains and the involvement of local administrations and agricultural and industrial entrepreneurs in pilot projects at regional or interregional scale. However, the process of transferring energy powers to the Regions did not develop a National Plan that sets out guidelines, rules and objectives, resulting in several conflicts of competence, technical-administrative and financial barriers.

The work was carried out based on this background with the aim of defining and planning agro-energy districts. The main objective was to identify suitable areas for designing an agro-energy district and to count the existing biomass quantity. The estimation of the latent installed power derived from biomass (e.g. agricultural waste, forest wood and energy crops) made it possible to reflect on the degree of sustainability at a local scale (Masera et al., 2006; Emer et al., 2011; Colantoni et al., 2016). The goal is to identify the contexts in which to set up an agro-energy district, or "networks of producers and transformers, also differentiated by type of energy produced, able to ensure energy quotas for a defined area, through an organization of distributed generation and such as to maximize the multifunctionality of agricultural enterprises in their various aspects" (Gaviglio et al., 2009).

As other European countries, the Italian rural landscape, typical for its peculiar crops and agricultural practices, has undergone intense changes in recent decades in the use of land for urban or speculative uses, leading to a loss of rural employment and, at times, to a consequent reforestation due to the abandonment of agricultural land (Bonet, 2004; Godone 2014; Sitzia, 2010; Sluiter and de Jong, 2007; Leal Filho et al., 2017). With the aim of consolidating realities definable as "agro-energy districts", the work is aimed at using GIS technologies to (i) identify the current state of a given area that presents the basic characteristics to undertake a circular economy. These areas may consist of different local realities. Consequently, during the analysis, it is necessary to verify whether the characteristics of the agricultural and productive system can be defined as a local or regional vocation (Gaviglio et al., 2009). From the production phase to the collection of crop products, very often the agricultural waste produced cannot be sustainably used. For this reason, their re-use for energy purposes corresponds to energy production at local and/or district level based on a kind of circular economy (Monarca et al., 2011).

The current decline of the Italian agricultural sector caused the abandonment of several agricultural areas (Bonet, 2004; Godone 2014; Sitzia, 2010; Sluiter and de Jong, 2007). Understanding and studying this phenomenon is essential before promoting a new local economy. GIS technologies therefore shed light on territorial difficulties and limitations. For instance, the problematic achievement of a certain economic activity may be linked to the complex locations, which compromise the safety of the operators working there. This aspect is often neglected and rarely integrated into the themes of agro-energy districts and circular economy. At this point, GIS technologies highlighted the contexts that can be included and become an agro-energy district, providing useful strategies and tools for planning and managing biomass at numerous territorial scales.

Safeguarding sustainable development of rural areas, another research work aims to strengthen the local economy in a territorial district in Sicily region (Italy) through the cultivation of hazelnuts. Proposing strategies and optimizing mechanization systems through geo-spatial technologies, the work suggests a potential reality based on the circular economy with the purpose of re-using agricultural residues for energy purposes.

Always based on the cultivation of hazelnuts, another research effort focuses on the Viterbo context. Biochar application in agriculture positively affects soil and water holding capacity. The latter property derives from the distribution and the degree of cohesion of the pores in biochar, which is contingent on the particles size and aggregation, e.g. organic matter content. The effect of biochar on water holding capacity is reliant on both the high internal surface area of biochar and the capability to aggregate soil particles with organic matter content, minerals and microorganisms. Increasing soil porosity also permits a better percolation of excess water to the deeper soil layers, therefore cumulative ventilation.

Near the province of Viterbo, the province of Rieti was studied. Protecting the surrounding environment, the most efficient technologies available by examining the experiences of small-scale local installations were detected. An innovative framework was based on the design of a complete plant for the energy production with a net power output of 4 MWe, which essentially consists of a combustion furnace with a mobile grid integrated by a superheated steam Rankine cycle (Hirn cycle), at an industrial site of the municipality of Rieti (Italy). The chief aim is to offer a complete investigation starting from a geographical analysis of the context, offering also three other tasks with the aim of: (i) assessing the biomass potential from a sustainable perspective; (ii) providing an economic accounting of an exemplary biomass plant in terms of its technical characteristics and performance; and (iii) evaluating social and environmental impacts. A representative biogas plant of small size (250 kWel) was also examined by Salerno et al. (2017)[1].

Regarding issues of soil consumption, another research effort was intended to offer suggestions for the agro-energy districts using a spatially-detailed diachronic information on the expansion of solar plants into Italian rural areas, supporting fine-tuned strategies aimed at reducing the environmental impacts of photovoltaic plants. In relation to solar energy, agro-energy districts can also be identified in photovoltaic greenhouse systems. Furthermore, an additional analysis carried

[1] Salerno, M.; Gallucci, F.; Pari, L.; Zambon, I.; Colantoni, A. (2017). Costs-Benefits Analysis of A Small-Scale Biogas Plant and Electric Energy Production. Bulgarian Journal of Agricultural Science 23 (3), 357-362.

out examines the shading of PV panels of a prototype greenhouse, placed in Viterbo, that enables an environmentally adapting to the intrinsic characteristics.

Related to the primary sector, the performance of crops cultivated in photovoltaic greenhouses was also observed. The work detects the shading effects of PV system on some flowers growth (iberis, mini-cyclamens and petunias), located in Sanremo (Italy), guaranteeing an optimal underlying environment in most lighting conditions and letting through more light when it is required for the needs of crop plants (or in cloudy weather). Furthermore, it is expected that this system also delivers an income integration to farmers.

Agriculture is a relevant economic sector in Italy, offering several valuable products, such as wine. The identification of agro-enegy districts was additionally carried out based on vineyards. Examining areas located in the provinces of Treviso, Pordenone and Udine (Northern Italy), a descriptive stage of the Italian wine sector was applied in terms of production data concerning both offer and foreign trade. Then, a spatial exploration was performed by observing landscape changes and land-use dynamics. In this respect, the Italian regions that have witnessed a greater growth for the wine sector in the last years emerged. Veneto region was one of these contexts and therefore was investigated. An estimation of the amount of biomass that can be obtained from the contexts considered allowed an assessment of energy and potential mechanization processes, as well as an economic evaluation. Compared to other agricultural activities, the wine industry as an evolving economic activity resulted to be very inclined to achieve a rich set of tasks through its specific organizational capacities and resources (Annunziata et al., 2018). Furthermore, the effects of recent trends in the wine sector are visible on the local landscape (Mariani and Vastola, 2015). The spatial elaboration was implemented through a GIS (Voivontas et al., 2001). Finally, before the conclusions, the thesis reports also research works not yet published, which have been mentioned and briefly described.

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2. Study Contexts

The research has been developed on different contexts of the Mediterranean Europe. The choice to focus on these contexts is because they are very similar and can be comparable; however, they have peculiar and divergent characteristics, linked to their history, culture, society and economy. The main contexts investigated are:

- Italy, particularly Tuscia's area with the city of Viterbo, the metropolitan area of Rome and other interesting local areas;
- Greece, chiefly the metropolitan area of Athens thanks to the collaboration with national research institutions and Greek universities;
- Spain, mainly the metropolitan area of Barcelona thanks to the collaboration with the Autonomous University of Barcelona and the Valencian Community, thanks to the research period carried out in the summer of 2018 at the University de Valencia.

2.1. Italy

The Italian contexts have been intensively used as study contexts for various themes. Italy offers numerous databases in which it is possible to compare different areas also following the processes of urbanization, changes in rural landscapes, forests and peri urban areas (Figure 2.1). With a sustainable development perspective, the Italian contexts have been studied strongly in relation to the environmental and energy components. In fact, Italy is characterized by undulated topography (23% lowlands, 42% uplands, 35% mountains) and multifaceted rural landscapes with conventional crop systems shaped by spatially-varying environmental conditions.

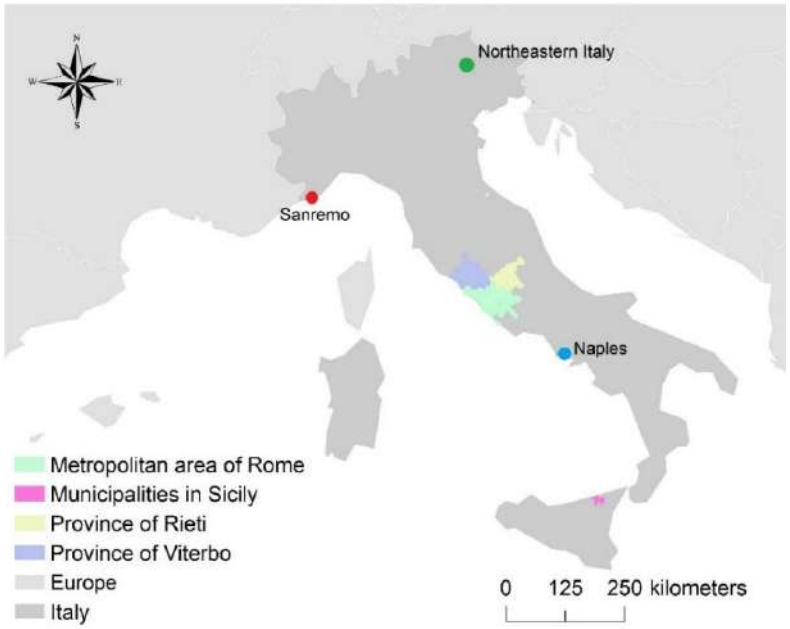


Figure 2.1. Italy and the local contexts analyzed.

Viterbo is a central Italian city of about 70,000 inhabitants in the Latium region. Its province is also known by the name of Tuscia (Di Felice et al., 2014). It is bordered to the north-west by Tuscany (provinces of Grosseto and Siena), by Umbria on north-east (Terni province), by the province of Rieti on the east, by the capital city of Rome on the south and by the Tyrrhenian Sea on the west. The city

is located at 326 meters a.s.l., with an area of 406.23 km². The slight slope, on which stands the city center, extends west to the Maremma plain.

Tuscia coincides with the province of Viterbo (NUTS3 region), located in the north of Lazio region, in the heart of Italy (Di Felice et al., 2014). It includes 60 municipalities that surround the capital city of Viterbo that is located enough centrally. This area has a total surface of 3615.24 km², with a population density equivalent to 87 hab./km². It confines with Tuscany on the north-west, with Umbria on north-east, with the province of Rieti on the east, with the metropolitan city of Rome on the south and with the Tyrrhenian Sea on the west.

Central Italy, separated from northern Italy by the Apennines, is a polarized region in urban and rural areas with traditional landscapes located in the internal mountainous zone (Salvati et al., 2014a). In fact, Tuscia has a rich history of civilization, traditions and events, which date back to the Etruscan period and the Stone Age (Gobattoni et al., 2015): in fact given the numerous historical vicissitudes, the name "Tuscia" was attributed to that area previously occupied by the Etruscans, including the northern part of the Latium region (including the provinces of Viterbo and Rome) and the southern part of Tuscany. Currently the territory of Tuscia refers largely with the province of Viterbo (Di Felice et al., 2014): it is a historical context, full of art, archaeology, uncontaminated landscapes, picturesque medieval villages and nature. Tuscia can be considered as one of the rare Italian reality in which the spatial dynamics and urbanization processes have had to adapt to the lifestyle of its inhabitants.

The province of Rieti was investigated for energy purposes, with many forest and natural environments. It is an Italian central province situated in the Lazio region that has Rieti as its capital city, covering an area of about 3000 km² and including 73 municipalities.

The metropolitan area of Rome includes the territory with the capital city of Rome and the neighboring municipalities that have close economic, cultural, social, territorial integration relationships with it. The administrative province of Rome, central Italy, extends nearly 5350 km² of land characterized by a complex mosaic of natural, semi-natural, rural and urban systems. Over 66% of the population residing in the Rome's province currently lives within the Rome's municipal boundaries, corresponding to nearly half population residing in the administrative region of Latium, including Rome and other 4 provinces (Latina, Viterbo, Rieti and Frosinone). In the last decades, resident population has declined moderately in downtown Rome, in line with what was observed in other Mediterranean cities (Terzi and Bolen 2009; Chorianopoulos et al., 2010; Cuadrado Ciuraneta et al., 2017).

While informal developments in Rome were partly grounded in planning decisions of the Fascist regime and the post-war coalitions of developers and decision-makers (Seronde Babonaux 1983; Insolera 1993; Clementi et al., 1996), spontaneous building was a frequent type of urban expansion in the 1950s and 1960s (Costa et al., 1991). Informal settlements rose thanks to a rapid demographic boom, a consistent growth of the construction market and a weak policy of social housing (Krumholtz 1992). With the economic expansion of the 1960s, Rome's growth was partly aligned with the prescriptions imposed by the Strategic Master Plan enforced in 1962 (Clementi and Perego 1983). Ex-post modifications in the legal prescriptions of the 1962 strategic Town Plan were progressively introduced in the 1960s and 1970s (Insolera 1993), counteracting the expansion of illegal settlements into rural areas (Seronde-Babonaux 1983). Population decline in the core city was

observed since the late 1980s, with more than 2.5 million people residing in Rome municipality (2011), and with a suburban population growing slowly up to the late 2000s (Violante 2008) and then stabilizing to less than 1 million residents (Tombolini et al., 2015).

The need to a new town plan recovering informal settlements and orienting future expansion towards defined spatial directions was emerging in the 1980s and the 1990s, with consolidation of new forms of mass commerce, tourism and advanced industry (Archibugi 2004). Managing wider spatial contexts, "structural" and "strategic" plans have been implemented in the 1990s with the aim to provide flexible instruments to governance action and efficiency in land-use regulation (Watson 2009). Between 1993 and 2008, planning measures were announced to promote polycentric development (Salvati 2013), reinforcing some metropolitan poles, stimulating concentration of economic activities in peripheral districts and re-locating some economic functions in residential sub-centers (Allegretti and Cellamare 2009). However, this strategy was applied partly and resulted sometimes unsuccessful (Gemmiti et al., 2012). A new strategic Town Plan was approved in 2008, combining rules and guidelines aimed at a more coherent metropolitan design, dedicating attention to issues of urban decentralization and polycentric development, environmental protection, provision of high-tech services, cultural and historical heritage (Tombolini et al., 2015).

Linked to the section of agro-energy districts, 10 municipalities in the Sicily region were investigated being part of the National association of hazelnuts. In these contexts, many hazelnut plantations appear to be woods. Hazelnuts have well-adapted in the Nebrodi mountains (Gianguzzi et al., 2016), but very often are in problematic areas to reach and work in safety. Sicily is a Southern Italian region with many forests and fields designed for agricultural activities. Among these, hazelnuts have settled as one of the most visible crops in the north-eastern part of Sicily (along the Nebrodi mountains), given the confident morphological and climatic features. The cultivation of hazelnuts in Sicily covers a surface area of 16,482 ha, producing each year around 20,430 tons. The diffusion of hazelnut trees in this context took place in 1890, after the crisis of gelsiculture. Today, thanks to their ease of adaptation, dense root system and profitable productivity, hazelnuts are the predominant yield of the Nebrodi agrarian landscape. In this regard, the municipalities of the province of Messina of Castell'Umberto, Montalbano Elicona, Sant'Angelo di Brolo, Raccuja, Santa Domenica Vittoria, San Piero Patti, San Salvatore Fitalia, Sinagra, Tortorici and Ucria are part of the National Association of Hazel Towns ('Associazione Nazionale Città della Nocciola'), representing the region of Sicily.

The provinces of Treviso, Pordenone and Udine, in the northern area of Italy, were assumed as local case study since it is strongly devoted to the wine production. Given the recent and exponential development of the wine sector in this context, the economic realities analyzed are placed in some municipalities of the provinces of Pordenone, Treviso and Udine, which recorded a growing surface area designed for vineyards with positive rates, respectively of 9, 21 and 23%.

Sanremo is a coastal town in north-western Italy, in Liguria region (geographical references: 43°49'3''N - 7°45'50''E with an axis of orientation of the roof ridge of 351°N). This place was chosen for a PV study, where a greenhouse prototype is located at the Regional Institute for Floriculture (IRF), in Sanremo.

The metropolitan area of Naples indicates a vast territory of Campania region that for economic, urban, social and service issues, as well as historical and cultural, is linked to the city of Naples. For

the work carried out, this context has been used as an area of comparison with other European areas about territorial changes and the difficulty of spatial planning. In Naples, sprawl led to the conversion of agricultural land to massive impervious areas, deteriorating the environment. Urban congestion and chaos are the dominant characteristics of the metropolitan area of Naples (MAN) are, particularly in the urban outskirts (Papa et al., 2009). The neighboring areas of Naples progressively grew into an intricate urbanization process (Coppola, 1991; Coppola and Viganoni, 1997). However, in these new urban areas, over-building and illegal construction coexist together with substantial attractions in relations of accessibility and productive sites (Amato, 2015). Therefore, the urban conditions of the outskirts of Naples are amongst the major concerns. Numerous environmental and social difficulties emerged for which coming up with a solution represents one of the major challenges. Urban boundaries have moved together with the rapid expansion. Today Naples has reached areas well beyond its local administrative boundaries (Papa and Mazzeo, 2014), resulting in the effort to govern over these residential and industrial sites (Gargiulo Morelli and Salvati, 2010).

2.2. Greece

Greece has been one of the most studied contexts, both starting from the processes of urbanization and related to land use changes related particularly to peri urban landscapes (Figure 2.2). Greece (301,330 km^2) is a European country with a divided urban system centered on Athens, the capital city, and Salonika. Major urban centers include Patras in the Peloponnese and Iraklion in Crete. Approximately 80% of Greek land is composed of mountains and upland. The larger planes are placed in the prefectures of Thessaly and Central Macedonia, which are key areas devoted to large-scale, high-input agriculture. Greece constitutes the most southern continental part of the Balkan peninsula, which expands to the south, embraced by the Peloponnese peninsula, the Aegean and Ionian Seas, separated by the Corinth Channel. The country includes more than 1,500 islands in the Aegean and Ionian Seas. The most important islands are Crete, the Cyclades and the Ionian Islands.

Figure 2.2. Greece and the local contexts analyzed.

Athens is the Greek capital and represents a determining case of the Mediterranean city (Leontidou, 1990). Its metropolitan region (Attica region) encompassing the greater Athens' area, extends nearly 3000 km² in Greece, being administered as a regional authority classified in the Nuts-2 level of the European Territorial statistical nomenclature defined by Eurostat. Being partitioned in four local prefectures, Attica's land consists of uplands and mountains (up to 1413 m a.s.l.) bordering the urban area of Athens and three coastal plains (Messoghia, Marathona and Thriasio), together with some islands among which Salamina and Egina are the most populated (Rontos et al., 2016).

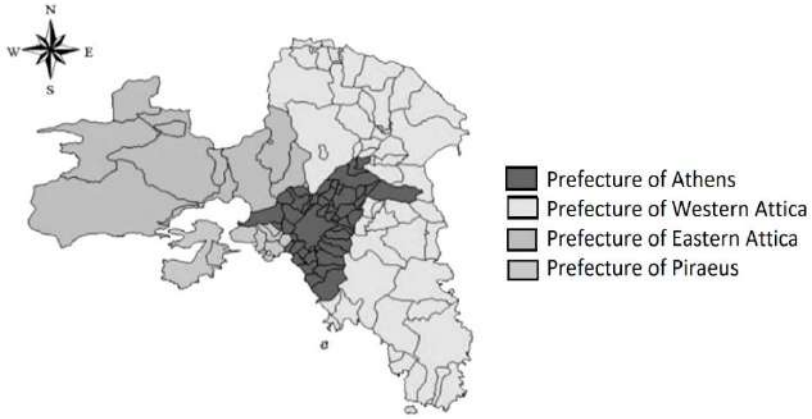


Figure 2.3. Administrative organization of Attica: the four prefectures of the region.

Although rocky soils and vegetation cover adapted to semi-arid climate regimes may reflect vulnerability to soil erosion and land degradation processes observed in the region since millennia (Economidou, 1993), the area presents historical settlements inhabited since millennia due to favorable climate and proximity to the sea. The Piraeus' harbor, intrinsically connected with the Athens' urban area, is one of the largest in the Mediterranean basin, supporting commercial flows between western and eastern Mediterranean since centuries. The geography of transport networks in the area well indicates a spatial structure concentrated in a central city (the Athens-Piraeus node) with surrounding rural areas developing rapidly around infrastructures and along the sea coast (Chorianopoulos et al., 2010; Delladetsima, 2012).

The interest in providing a detailed analysis of the Athens' urban development in the 20th century derives from various reasons. To begin with, Athens' development is a typical example of the trajectories followed by Mediterranean cities, that are now experiencing a transformation from compact growth to sprawl and polycentrism (Chorianopoulos et al., 2010). If until the 1990s Athens was considered a model of compact growth, today cities are attracting the attention of many researchers for their progressive deviation towards sprawling patterns of urbanization (e.g. De Rosa and Salvati, 2016). Understanding reasons and causes behind this transition from compact development trajectories to the current "spillover" process is functional for a better comprehension of urban sprawl in the Mediterranean region (Delladetsima, 2012).

Studying its long-term expansion has revealed a tangible trend in the Mediterranean region, which is connected to the development of new intermediate density settlements and the successive relative self-containment of new built-up areas (Salvati, 2013). The sprawl in Attica has given rise to a transition from a traditional urban-rural polarized landscape to a diffused urban asset that spreads over the available land, chiefly sacrificing agricultural and forested contexts (Chorianopoulos et al., 2010).

The sprawl process in Attica is relatively recent (Chorianopoulos et al., 2010; Salvati et al., 2013). However, major concerns arise from the fact that even regions characterized by a strong tradition of compact growth are slowly being invaded by sprawl patterns of urbanization (Sateriano and Salvati, 2016). As the population of the Mediterranean has approximately stabilized on constant values, the necessity of converting more natural land to urban use is not completely justified. With the current environmental and economic challenges, switching from compact growth to sprawl patterns is not the case, especially in the light of increased urban competitiveness amongst the regions of the world (Chorianopoulos et al., 2010). The analysis of negative effects connected to the dispersive process shed lights on urban policies for controlling the phenomenon in such a delicate moment of urban and economic crisis (Pagonis, 2013; Sateriano and Salvati, 2016).

2.2.1. Urban history of Athens

After years of continuous elaboration of regulatory plans, basically based on the proposal prepared by Vasileiadhs in 1966, the Regulatory Plan (PR) of Athens prepared by the Doxiadis Technical Study was approved in 1985 by the Ministry of Environment, Planning and Public Works (ΥΠΕΧΩΔΕ), and thus entered into force during the legislature between 1980 and 1985, with Minister Antonis Tritsis (Chorianopoulos et al., 2010). This was a great innovation for Athens and, in general, for Greece. Since until then, despite the numerous proposals and the various studies, it was never possible to approve and make a regulatory plan operational. The plan included all the basin of Attica, as well as all the peri-urban areas which had not yet been affected by the urban development regulations. For this, peri-urban contexts were defined "out of plan," as they were not included in a regulator plan. While the Regulatory Plan (PR) was still in force under the 1992 law, its various features have undergone major changes, such as the concept of "deconcentration of services."

Cited article

Salvati, L., Zambon, I. (2017). Social Forces, Urban Growth, And Town Planning: Evolving Visions From A Contemporary Metropolis. Current Politics & Economics Of Europe, 28(2).

The division of Attica region in the so-called "suburbs" was designed by Doxiadis and envisioned in the 1985 regulatory plan. Doxiadis's basic idea was to give the citizen pedestrian access to the main functions. However, with Law 2052/1992 "Measures to Combat Smog and Urban Adjustments", it provided for the abolishment of the disperse local centers at the municipal level, adopted by Law 1515/85, and the creation of four large centers, called "Secondary centers of territorial division of the Attica basin" to decongest the core of Athens and Piraeus. In addition, the PR provided for the shift of governmental government services to the west of Attica with the intention of refurbishing those peri-urban areas. This de-concentration was never being implemented, in the absence of a true political motivation, like other proposals of Doxiadis, e.g., controlling informal housing and the effective application of PR with implementation plans that can regulate edification.

Doxiadis analysis concerned the regional population growth and the expansion of the capital city from 1951 to 1971. After 1990, there was a decline in Attica's housing growth. The basic idea of PR was to de-concentrate the Attica basin. Especially, the "extended center" area would retain the directional hub, while all other functions not related to Attica would be decentralized. Athens was considered autonomous and organized into five subdivisions: Lekanopedio (Aktiba Basin) and

Salamina Island, which refer to Athens City Hall as the center; West Attica with Megara center; North Attica with center in Kapandriti; Eastern Attica with center of Lavrio and Attica island with center of Egina. While providing for the expansion of existing towns, the PR introduced the protection of some open spaces and green areas. For instance, in the case of the Lavreotiki district, residential space was divided into summer residence, town center, industrial zone, shopping area, nature reserve and a roadmap including roads, trains and harbors. The plan (Figure 2.4) did not ignore the abusive expansion, already existing in Attica, and was moved by the predominant determination to reorganize the built-up and to plan expansion respecting the environmental heritage (e.g. mountains, beaches etc.).

Another aspect concerned the so-called "city of public employees" plan, an expression of Dioxadis studies in Athens since the 1960s. It was the possibility of urban expansion toward the sea for second homes (holiday homes). The Doxiadis Plan for Athens-Oikoumenopoli proposed in 1960 deserved a short discussion, as it was the forerunner of the present one and because it prefigured the new center of Tatoi in the same peripheral area. It was a well-organized proposal. Although, it was preceded four years earlier by that of topographer A. Siokos, who had formulated a similar proposal for the new center on the bank of the river Kifisos, where he designed the "city of Public employees" for Athens. In the Sokos Project, there were the main axes that will be implemented later as the National Road and Attiki Odos, already appearing in the Doxiadis Plan of 1945.

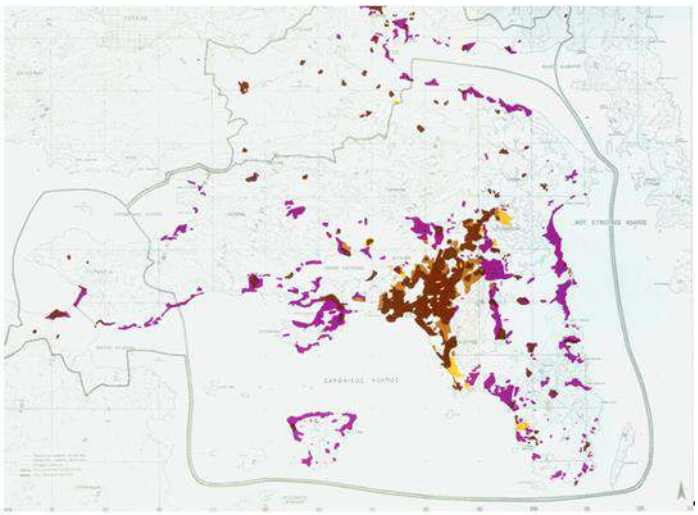


Figure 2.4. Informal housing by decades in Attica (1950s: dark brown; 1970s: purple; areas entered the PRG: light brown; newly built settlements according to the PRG: yellow). Source: PRG Athens published by TEE.

The main actions envisaged in the 1985 plan consisted of the Attica division in centers, the location of the new Athens Airport in the Spata area and the abandonment of the old airport. This decision was part of a new axis for public and private transport, which also included changes related to the development of the ports (as in the case of Falirò), as well as a series of proposals for road extension, construction of new Fevered for the Olympics and industrial development (shown in violet in Figure 2.5). In brown there are homes, the "holiday homes" in yellow, the industrial zone in violet, the national directional centers in red, the natural reserves in dark green, and the agricultural areas in light green. The location of the new Athens Airport in the Spata area had a strong impact on the territory. Figure 2.5 respectively represent the impact from the point of view of noise and marine pollution. The controversy around choosing the location of the new airport

turned on in following years. However, the criticisms and the protests did not concern the agricultural aspects, but rather the great commercial land-related interests and the firms that would win the road construction contract. Both the airport and Attiki Odos, the connecting road to the city and the national roads, were built by companies linked to German interests.

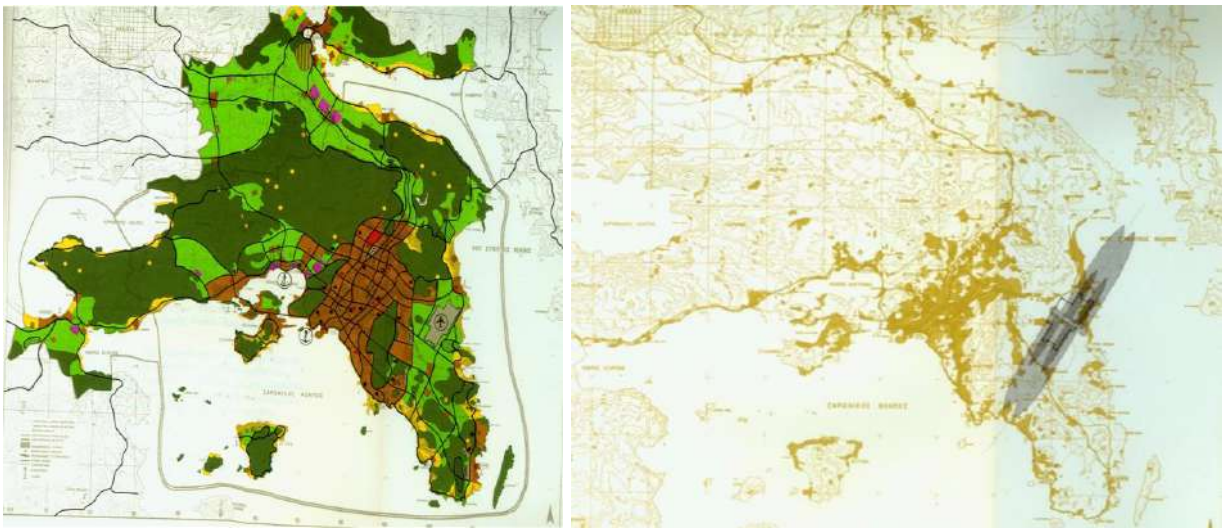
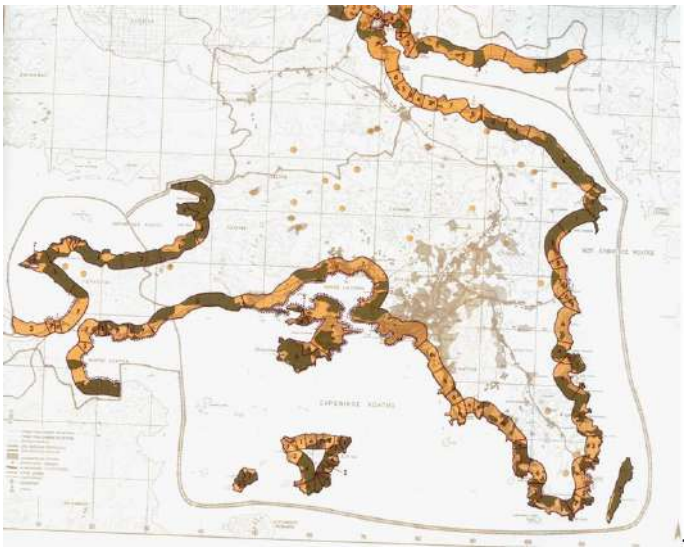


Figure 2.5. Destinations of use with the new Spata airport, forecast for 2000 (left). Athens and noise area caused by the new airport (right). Source: PRG Athens Published by TEE.

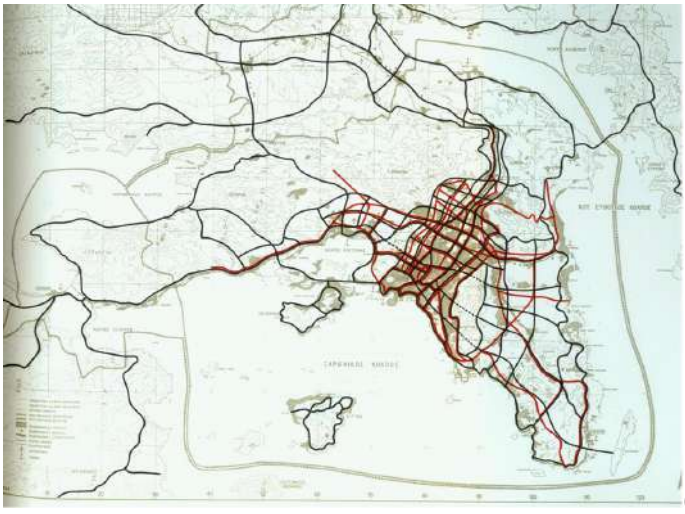
Sarigiannhis emphasized that the whole territory was considered potentially buildable. In Europe, urban space as a commodity concerned only large companies that chose to invest in contexts, such as abandoned port facilities, old industrial or degraded residential areas. These real estate speculations attracted a large volume of investment, creating great profitability. Examples of this type can be traceable in Berlin (Potzdammer Platz), Vienna (Gasometer), Helsinki (Pasila), Paris (Defance) and London (Docklands). The Plan of Doxiadis was based on the elaboration of the Plan presented by himself in 1960 (but also on the 1945 editions), in which the axis of today's Attiki Odos road was already present, linking the Athens-Thessaloniki and Athens-Patras National Roads with the new airport. This artery run a large part of Attica, crossing original agricultural areas, which, after the construction of the highway, became residential. The most impacted proposal relates to the definition of the land-use destinations, shown in Figure 2.6a, and comparable to the previous uses, as shown in Figure 2.6b. Though, in Athens (already largely constructed in the absence of real territorial planning), the 1985 plan remained in many respects inadequate since it dealt with the obstacle represented by the urban context that has been achieved with the previous plans, studies and proposals. In other words, while it had materialized in the proposal of the 1960s with solutions considered at the time of "progressive," in the 1980s the plan of Dioxadis lost its innovative character. The 1985 PR clarified what it has been achieved or proposed above. In this respect, it was useful to recall, for example, that, in 1964, Wilbur Smith and Association had the task of drafting the Urban Traffic and Mobility Plan for the City of Athens. Smith's proposals, characterized by ideas and interests considered to be American footprints, were at least incomplete regarding transport, especially as to how they promoted the use of the machine. It should also be noted, as Sarigiannhis recalls, that at the same time Smith's study of the Traffic Plan and Mobility Plan for the City of Helsinki proposed the demolition of the tram network and its replacement by buses and a metro line. A proposal that Finnish town planners had rejected. In Athens, Venizelos had preceded him and had demolished the tram since 1955. Therefore, the current PRG has had to adapt to the road

system already built based on previous proposals, in which the lines proposed by the new PRG are compared with the Smith plan (Figure 2.6c).



(a)

(b)



(c)

Figure 2.6. (a) Expansion possibilities for holiday homes. Source: PRG Athens published by TEE; (b) Land zoning (1945: left; 1960: right); and (c) in black, the lines proposed by the PR; In red, the Smith plan. Source: PRG Athens Published by TEE.

Among the wills expressed in the new plan, there was also the safeguarding of the rural territory (Figure 2.7). But the natural reserves that exist today in Attica were far removed from these images, described in the 1980s before the built-up boom, allowed by way of the PR of 1985 from the implementation plans of the peri-urban area, implemented after the continuous wildfires. This was the case with Penteli Hill. Sarigiannhis really believed that the Ministry seemed to have lost control of the situation, venturing into micro-operations or "illusory" card exercises that have no hope of being realized. Its main activity appeared to be to approve the urban expansion of Athens to the burned areas of Penteli, where there will be villas next to a fire. Specific attention in the new plan was dedicated to the archaeological areas of classical antiquity. Clear zones were identified in mixed districts with important archaeological areas and in dark green the free zones with important archaeological reliefs that required greater protection. The plan focused on visible things, settlements, infrastructures, plants, transport networks, new works, government services, hospitals, and agricultural areas. Instead, it did not consider intangible aspects such as, for example, social relationships, power relations, and meanings attributed to places by local societies.

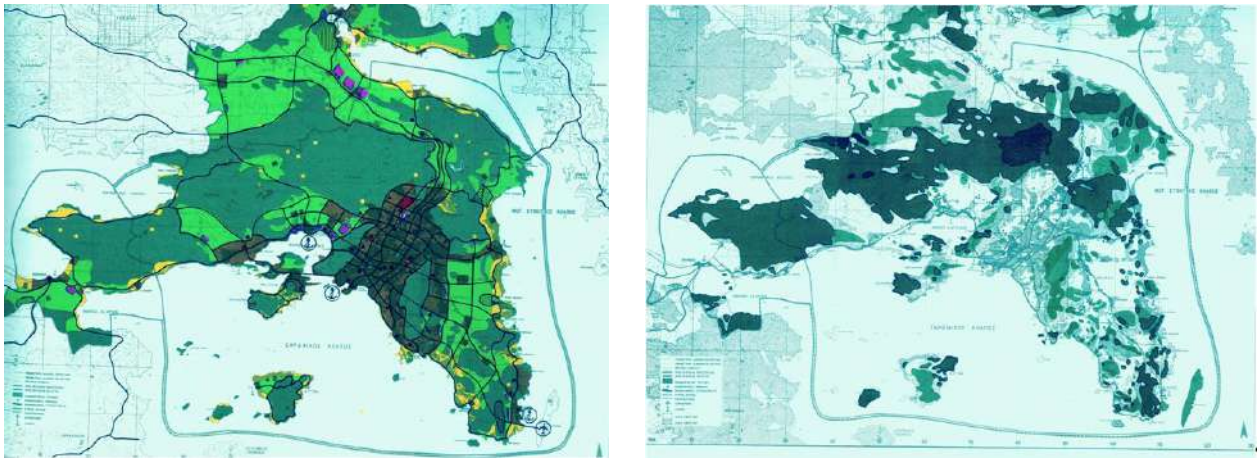


Figure 2.7. Map with PR destinations. Dark green identifies natural reserves, light green crops, and violet industrial zones (left). Source: PRG Athens Published by TEE. Archaeological areas to safeguard (right). Source: PRG Athens Published by TEE.

The approval of the plan, by law 1515/85, made it possible for the first time to implement the planning in Athens and other cities. The first major reform was the revision of Law 1515/85 by Law 2052/1992 "Measures to combat smog and urban adaptation." The new law proposed the abolition of dispersive local centers at the municipal level - adopted by 1515/85 with the idea that the citizen should have pedestrian access to the main functions - and the creation of four large centers, which are called "Secondary centers for the territorial division of the Attica basin (Λεκανοπεδίο)" with the aim of decongesting the agglomeration of Athens and Piraeus. This de-congestion logic, already present in the law AN395/68 (law for maximum heights, percentage of edification on soil, free-standing silhouette system from construction lines) had produced intense construction in urban areas. The 1992 regulations also tended to meet the demand of entrepreneurs who perceived the decline of construction activity in the center, due to the inacceptable life quality and hoping for a new built-up boom in the suburbs to be realized with πολυκατοικία, multi-storey buildings (condominiums), which has been verified.

Peripheral areas were considered out-plan" until the PR of 1985, indicating land deprived of PR and often without implementation plans for roads and services. These were farmland or

spontaneous vegetation (provided they do not coincide with protected natural areas). Most of them were of interest to the implementation plans issued by the technical offices of the individual municipalities and specifically designed to grant building permits. Generally, building rules allowed a low cubicle with respect to the surface to avoid large heights and to continue to consider those "rural" areas, regardless of agricultural use. In the period of dictatorship, the laws inspired by populist politics have allowed, even in the "out-plan" land and condos with multilevel. On the other hand, housing conditions in the degraded center of Athens have already lowered urban incomes and witnessed the first demographic displacements from the core of Athens to the peri-urban context, seeking greater living, environmental quality and less polluting. In the absence of an approved plan, the result was the proliferation of building expansion throughout the peri-urban area, through pervasive and meticulous construction speculation. The phenomenon of *αντιπαροχή*, the sale of the land by the owners to the manufacturer in exchange for apartments on the same site, has spread, changing the appearance of rural areas.

The new "centers," described by Sarighiannis, in rural contexts were: Maroussi (made by OTE, headquarters of Greek public telecommunications, equipped with metro line), Haidari (military zone), Menidi (public land in Amygdaleza) and Elliniko (ex-airport). Sarighiannis described how, already in the 1980s, small and medium-sized "shopping centers" were built along the road axes around the more expensive suburban areas (Viale Kifissias, Viale Possidonos etc.), which moves buyers from the urban core to the periphery, after law AN 395/1968. The creation of large multifunctional centers (malls) was already a common practice of capital in the United States since 1970 and shortly afterwards in Europe. Sarighiannis pointed out that the "shopping centers" were in isolated rural areas, where large open spaces existed and where the major traffic routes were present, which made it easy to access. In this way, the capital can take advantage of public land with concessions of 30, 50 or 90 years at an unreasonable price, while it would be too demanding to buy land from the private. In the years after "Tritsi," norms such as Law 2508/1997 were issued about "sustainable city expansion and other provisions," which defined concepts (such as the General Urban Plan - Master Plan ΓΠΣ, ΣΧΟΑΠ Ρ, Open City), which were partially applied (such as the Master Plan), while other concepts (such as open cities) remained on paper.

The latest intervention during the urban plan of Athens was in the absence of a new Master Plan, under the appearance of national importance of the Olympic Games in 2004. Beyond the great impact on the public debt, the Olympic Games have left for Greece important projects that were managed by large private enterprises. The shopping center "The "Mall Athens," the new "Neratziotissa" station on the HSAP electric train line and the Proastiakos perennial train just few steps from the Kifissias Avenue, the huge ping-pong building next to Omorfokklisia (which is becoming the Mall), the Press Office Center at Kifissias Boulevard (CBS and others) have become another Mall owned by the same entrepreneur and other similar initiatives, such as the Agios Kosmas beach converted into a giant marina for private yachts with its services, the beach of the Faliro Delta and the "Olympic plants." The case of Skinias, the port of Faliro and the "International Center" of the Olympic Village now remain unused resources for future investments.

With the current crisis, given the socio-political conditions of Greece, there is no prospect of a new PR for Athens. The enormous urban expansion and the comprehension of the great works for the Olympics has created a favorable ground for the crisis, by decreasing urban incomes. The deconcentration of services, as envisaged in the 1985 PRG for the lightening of the center, coupled

with the "growth of the land market" as defined by the expansion in the peri-urban area, led to the isolation of the main services.

In the hypothesis that Athens's building development continues, Doxiadis proposed to carefully study the built-up settlements by examining growth factors to identify the expansive expansion model in view of achieving the "ideal city." Ultimately, the PRG summarized the proposals that appeared in the plans that were drafted until the 1980s. Many concepts were common, such as the Athens division in "peripheries." The plan was based on general concepts related to the expansion of the metropolitan area and avoided making radical changes, which were, however, difficult to apply, given the radical transformations made in the meantime outside of any planning norm. Doxiadis was considered an important urban planner for his ideas around the ideal city that emerges from his analysis after World War II but significantly in the 1960s with the proposal for Athens-Oikoumenoupoli (Figure 2.8).

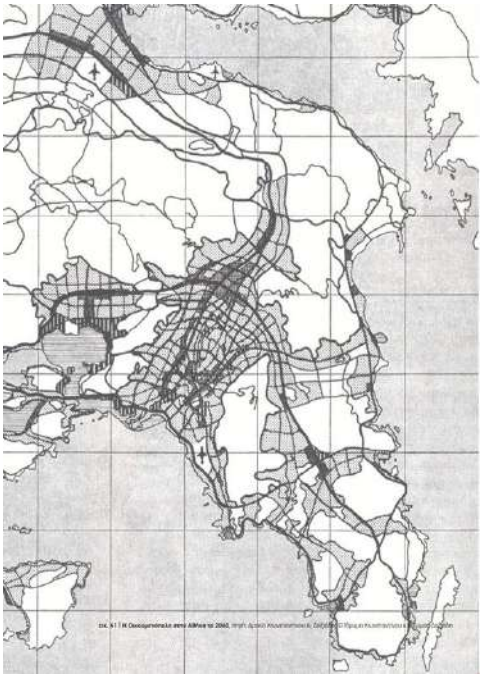


Figure 2.8. Doxiadis' Oikomenoupoli forecast for 2060. Source: Ioannidis, 2012.

2.2.2. Town planning and the expansion in Athens

Looking at the historical development, particularly within the urban network of the country, the predominance of Athens was well-known since the 1950s at the expense of all other Greek city centers. Attica, where Athens embodies the capital city, is the heart of territorial development of Greece (Chorianopoulos et al., 2010). The increasing imbalance has continued until the end of the 1970s. In the subsequent years, there was a progressive retard and the corresponding stabilization of urban aggregates. In the modern globalized economy, Athens is the only metropolitan center with which Greece can claim an international role (Petrakos and Economou, 1999; Beriatos, 1996a, 1996b; Beriatos and Gospodini, 2003). Most of the administrative, academic, research, sport and cultural activities were concentrated here, as well as important archaeological sites. The population of the Attica region was 3,756,600 in 2001, covering 34.3% of the total Greek population. The regional size was one of the major urban agglomerations, which act as a catalyst for the Greek economy.

As a characteristic Mediterranean city, Athens experienced an unplanned mode of urban expansion (Gospodini, 2009). Athenian growth trends portrayed a city that followed an un-designed way, based on small, self-financed property development schemes, with restricted public expenditure for urban infrastructure (Economou et al., 2007; Mantouvalou et al., 1995; Chorianopoulos, 2003). Until recently, the only normative planning document for the metropolitan area of Athens was the General Regulatory Plan (Ρυθμιστικό σχέδιο της Αθήνας). It was approved in 1985 (Chorianopoulos et al., 2010). It was a traditional document which dealt with the land-use regulation, zoning and location of the main infrastructures.

The first attempt to change the traditional approach to territorial planning and to introduce a strategic perspective was proposed by the Ministry of Planning, Environment and Public Works in 1994, with the ATTIKI SOS Plan (Pagonis, 2013; Vellopoulou and Ashmore, 1998). It was a non-regulatory action plan, which made extensive references to the need for a sustainability strategy. Ambitious goals were set to promote sustainable development to make the capital city and its entire metropolitan area the most important cultural and environmental resource in Europe. Subsequently, the same Organization for the Athens Regulatory Plan, having taken note of the changed conditions and new trends in the area, took the initiative to launch a review of the Regulatory Plan (2000).

The new plan introduced significant elements of strategic planning. During the preliminary stage, proposals involved central, regional and local administrations. The Athens Regulatory Plan also promoted a competition (2003) for the development of an implementation and operational specification of the regulatory plan, aimed at speeding up implementation procedures and encouraging coordination between the different programs and projects. A further initiative in the direction of a strategic approach to planning the Athens Metropolitan Area was directly promoted by the Planning Ministry, which instructed a group of experts to draft a strategic plan, called the Strategic spatial development framework for Athens-Attica in 2004 (NTUA, 2004; Serraos et al., 2005).

With 2004 Olympic Games, the debate on strategic planning became concrete and acquired important operational tools. During the drafting phase, a certain attention was paid to the European role that the Greek region should have played with the objective of a development strategy for the Athens-Attic region in the medium term (2006), but, above all, in the long term (2015), defining proposals for the Strategic Regional Planning Framework and Sustainable Development of Attica 2015, anticipated for a Strategic Action Program and the Impact Assessment of the Strategic Context on the Athens Regulatory Plan.

According to the prefigured scenario and considering the international conditions, a reinforcement of attention to peripheral areas is probable since Attica is located at a nodal point as barycenter between the Southeast Europe and the Arab world. The region has had a considerable potential growth, playing a chief role in its position. The development of possible scenarios was based on the following strategic objectives: (i) economic development and competitiveness into the national-international-European network; (ii) sustainable urban development, improving life quality and promoting the environmental and territorial protection; (iii) constant population in the region, promoting social development and cohesion; (iv) suitable strategic planning and balanced urban development at all levels of geographical units, redesigning administrative structures and metropolitan governance.

The proposed strategy was diversified in the medium and long term. Initially, it required the strengthening of the international relevance of the region in specific economic sectors. Subsequently, a more competitive policy for the expansion of Athens-Attica's international role was proposed in the long term. The Territorial Planning Framework covered the main metropolitan centers in the Greek (Athens and Thessaloniki) international ports, entrusting them with the gateway function to and from the European Union, the Balkans and other Mediterranean countries.

The first step in defining the objectives was to make any policy interventions of wider meaning. Attica should act as a development pole of diffusion dynamics. So, the entire Greek context and its population can benefit from the presence of an international metropolitan area by reducing Athens' weight, considered within the limits of its administrative boundary. The development of the international metropolitan area wanted to create the conditions for attracting cultural events, commercial transit, service center for macro-regional enterprises, to develop the infrastructure and telecommunications network. Especially, the great importance of Olympic games, in terms of public interest, involved substantial changes to the Athens Regulatory Plan, without following the usual procedural-administrative process.

The exceptional nature also was applied to lower administrative levels. In each of the hosting locations, the Olympic infrastructure, the Ministry of Planning and the Ministry of Culture in consultation with the Athens Regulatory Plan and the local administrations form an Integrated Plan which must be approved by presidential decree. These special plans contained all relevant elements for proper territorial integration of the areas concerned. The power of local governments has heavily been limited, guaranteeing them only a purely advisory role. Exceptional procedures also extended to land acquisition and expropriation, as well as how to use public assets and coastal areas. From this point of view, the strategic planning process implemented for the Olympic Games in Athens lacked one of the key features of strategic planning: the intergovernmental consensus and consultation with local instances.

The main implementing tools were the Special Integrated Plans, regarding physical projects and a series of cooperation pacts between Athens 2004 and the various institutions involved. Program Agreements, Protocols of Understanding and Program Contracts were signed with the involved Ministries, local administrations, public bodies and many associative organizations. The prevailing logic was the substantial spatial design. Assessments concerning the socio-economic impact of Olympic Games on the Athens metropolitan area largely remained on paper. The strategic projection of works took place almost exclusively based on transport and technological infrastructures. In fact, the analysis of the benefits of the Olympic Games was basically based on the impulse hypothesis that the entire agglomeration will receive from the new infrastructure system. At the metropolitan perspective, the approach was macroeconomic, looking at the impact of Olympic Games on tourism, balance of payments, investment, consumption and employment. The immediate result of the strategies and projects promoted for the Olympic Games has been the transformation of the entire Attica region and, above all, the metropolitan area of Athens into a colossal shipyard.

The Regional Development Plan of the Region (REC) 2000-2006, as defined by Law 2742/99 the Framework for Territorial Planning and Sustainable Development, extended far beyond the capital city, covering the entire geographical area of Attica, affected by commuting between places of residence and work, to underline interdependence with the capital.

Territorial planning and the foresee-ability of a country's sustainable development leaded to an approach that emphasizes the need to further integrate the regional area with Athens. A specific importance was the Athens-Lamia development axis, which was entrusted with the task of improving the prospects for the development of urban centers in the region. The vision expressed was that a polycentric structure will strengthen the regional and interregional expansion of some urban centers. It will lead to the spread of new development dynamics in metropolitan areas, creating influences beyond the administrative boundaries of the centers involved. The region was divided into homogeneous zones and common features in terms of geography, type and mode of development (Table 2.1.). Homogeneous geographic areas, without functional modules, showed each of its problems and constituted a reference framework for its environmental component.

Table 2.1. Homogeneous zones defined in the work.

A	Building Areas - Basin of Athens, up to the mountains, totally urbanized area.
B	Church of Imiastikopojimenes, Thriassion, Mesogion Plain - These are plain areas with a tendency to urbanization, where urban wars occur: in the form of residential development, development of productive activities; and of social development activities (education, recreation, sport).
C	Coastal Zone - All the Saronic Gulf (excluding the Thracian basin and Thriasio) and Evia. Mainly characterized by the development of residential areas, tourism, recreation. It is a completely rocky area with steep slopes and coastal forest presentations. Along the coast there are some settlements (Lavrio, Rafina, Nea Makri, Salamina, Nea Peramos).
D	Hills areas that can be divided into a peri-urban Basin area, Paliò Penteli, Markopoulo, Keratea, Lavrio and the plain of Megara, the northern part of Thriasio. This area has sporadic urban development, especially rural.
E	Mountains - natural hilly areas, forest with poor urban presence: Parnitha, Penteli, Imett, Aigaleo, Pure, Pateras, Citerona, Kapandriti Mountains, Marathon, Lavrio Mountains. It is characterized by the presence of small traditional villages around which urban development trends are manifested.
F	Islands: Spetses, Hydra, Poros, Egina.

The spatial organization of the Attica was the backbone of the structure of the Strategic Plan. Indeed, the various centers appeared to be the dominant elements of economic activity clusters, providing services to the population. These functions determined the configuration of spatial units, used as project modules or as spatial elements of metropolitan governance, through which the spatial regions and the competent authorities at different levels (e.g., district, county, local section) must be connected. At the same time, the centers represented the poles of the social structure, giving identity and physiognomy. In this sense, their design was of great importance. Particularly, the emphasis was placed on the territorial dimension of Attica's centers and space units to formulate a network of connections for the creation of the strategic role and territorial development of the Greek capital.

The composition of economic activity varied considerably over the last century. De-industrialization and outsourcing were obvious changes. At the same time, the composition of the tertiary sector has been changing, mainly by expanding the range of banking and insurance services. Therefore, the localization of services in Attica has also changed significantly. In fact, there has been a remarkable growth in trade and services in the north-west and south-east suburbs, and particularly in the influence zones of the main roads, between Mesogion and Vouliagmeni, and especially in residential areas. Particularly the center of Maroussi strengthened. A similar trend appeared in Piraeus. These were the subdivisions proposed by the 1985 plan, now considered to be overcome: The Basin of Salamina and the urban core of Athens; Attica Megara; Kapandriti; Lavrio; Egina. To these, there were 18 municipalities in the basin and 8 municipalities of Attica as centers of local

importance. Today a schematization is proposed in five levels of strategic importance of midpoints: at metropolitan Athens; at the local metropolitan level Piraeus Maroussi; locally Peristeri, Halandri, Kallithea, Glyfada; at the hyperlocal level, among others, Acharnon, Aigaleo, Pallini, Kifissia, Aghia Paraskevi, Nea Ionia.

Athens reserves the principal role. But, some of the functional activities have moved out in other urban areas and outside in other centers over the last few decades. For instance, the center of Marousi has shown great dynamism regarding the development of the directional sector and the trade. The hyper-local centers are fourteen, distributed in six space modules, as: Aghii Anargiri, Aigaleo, Haidari, Acharnon, Korydallos, Moschato, Kallithea, Nea Smyrni, Glyfada, Zografou, Aghia Paraskevi, Halandri, Kifissia, Nea Ionia and Maroussi. One of the main problems to be addressed with the action of the strategic plan is the spread of an extremely fragmented and dispersed urban fabric.

The presence of commercial, residential and industrial contexts separated roads and green-agricultural areas. As a result, the places where people live, work, buy and have fun were far from the main city. Low living density was the additional feature of sprawl. Buildings were made with a limited number of floors and were separated by each other. More parking and roads were functional for the use of the car, which allowed to reach, in a short time, considerable distances. The result was that the land was urbanized into a higher rate than the population growth. Since city growth was accelerating, built-up tended to be like each other. Such urbanization was characterized by extreme homogeneity and a predominantly uniform design of the built environment. Consequently, non-conforming soils were often used with incompatible uses where the concentration of central functions along the main roads, disparities in the quality of the residential environment between sectoral and territorial subdivisions, which tended to strengthen social separation between low-income or unemployed groups. To overcome this phenomenon, it has been attempted to provide guidelines for managing the layout and the environmental protection (Figure 2.9).

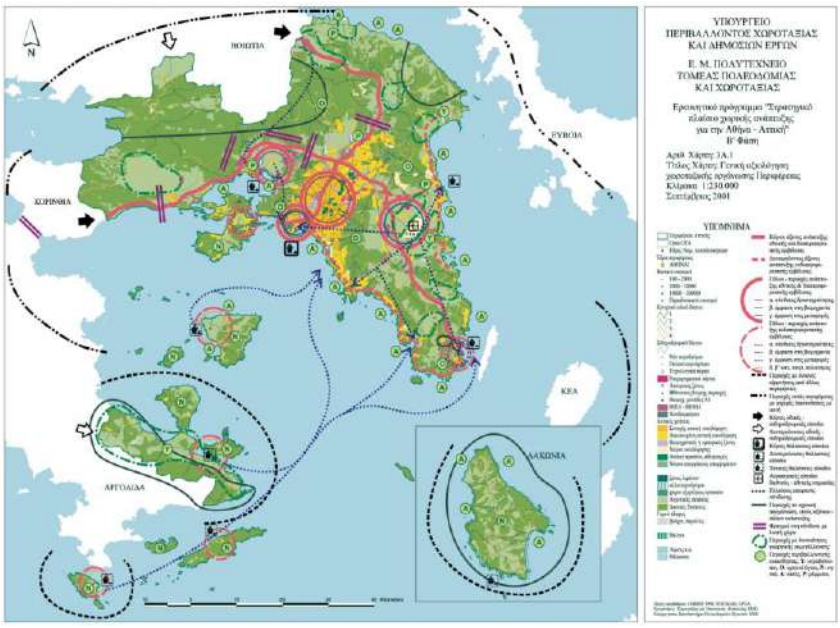


Figure 2.9. Extracted map of the environmental system. Source from http://courses.arch.ntua.gr/129909.html.

Town planning in Athens has proposed ambitious development policy objectives, which appeared to have not been achieved. The forecasts were to stabilize the economy, addressing the structural and financial problems and improving its competitiveness through a new relationship between the private sectors of the public economy and the profitability of the private enterprise (Karamanov, 2010). The region has been divided into areas that determine restrictions in relation to land use and new constructions, aimed at halting the uncontrolled spread of urbanization, removing incompatibilities, providing recreational facilities and others for the conservation and enhancement of greenery. Strong protection of the remaining free space has been sought: agricultural land, archaeological sites, green areas to guarantee development sites for the maintenance of ecological balance. For this reason, high security areas have been defined (e.g., archaeological sites, landscapes of extraordinary beauty or green protection or moderate urban expansion belts, farmland, beaches etc.).

Some rivers have been included in a list of environmentally-protected and protected nature conservation elements with the intention of protecting and managing these natural resources as an important ecosystem and integral part of the Attica's landscape. Plans and programs have been set up to create parks and public greenery, by implementing a complex and comprehensive environmental system for the region and integrating green urban areas with green corridors and environmental impact studies for the creation of new archaeological sites. Another problem covered by the Strategic Plan was to stabilize the population, i.e., maintaining a stable relationship between the population of Attica in relation to the overall increase of the national population. Therefore, policies aimed at reducing unemployment have been introduced, especially about the most disadvantaged categories: women, long-term unemployed, young people. Funds were approved for the primary sector. The production model in the secondary and tertiary sectors was restructured through the introduction of new technologies, through innovation, the creation of favourable conditions for the establishment of new national and international productive realities.

The Athens' metropolitan area was experiencing a long period of economic recession (Kaika 2012; Souliotis 2013). The 2007 crisis, combined with austerity urbanism and neoliberal policy reforms, resulted in unprecedented unemployment and job insecurity, severe income decline, poverty and social unrest (De Rosa and Salvati 2016). In a previous study on farmers' multiple activities in peri-urban districts of Attica (Moissidis and Duquenne 1997), nearly 40% of the household members who are in working age have declared to have two or more jobs, because peri-urban districts surrounding central cities offers more opportunities for alternative jobs than strictly rural areas.

2.3. Spain

Spain has been one of the major contexts of Mediterranean Europe studied and analyzed, thanks to relations with various Spanish universities, including the University of Valencia which hosted me as PhD candidate in the summer of 2018. Spain is subdivided into 4 administrative layers: national government, autonomous communities (level 2 in the European Nomenclature of Territorial Units for Statistics (NUTS) classification), NUTs-3 prefectures, and NUTS-5 municipalities. Spanish territory is administered by 17 autonomous communities (Figure 2.10): three of them (Basque Country, Galicia, and Catalonia) have especially strong allegiances to their own distinctive language, history, culture, and tradition (Giordano and Roller, 2004).

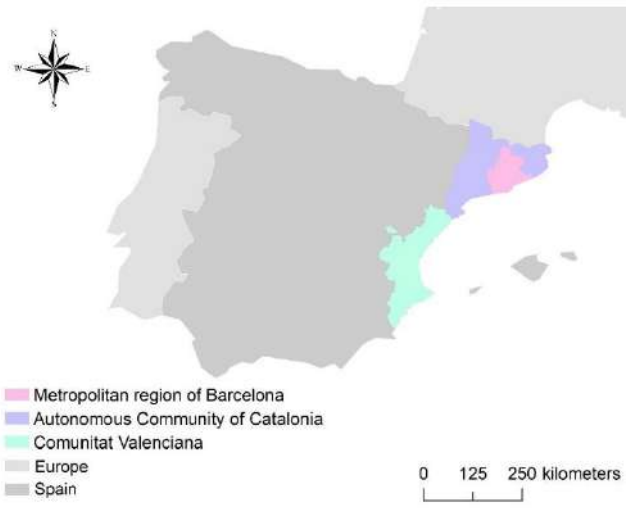


Figure 2.10. Spain and the local contexts analyzed.

The Autonomous Community of Catalonia in northeast Spain, a developed region extending nearly 32,000 km^2 along the elevation gradient from the Mediterranean Sea to the Pyrenees mountains, consists of 4 provinces (Barcelona, Girona, Lleida and Tarragona) and a total of 946 municipalities. Four out of 5 municipalities have fewer than 5,000 resident inhabitants, in contrast with the largest municipality and capital city, Barcelona, with 1.6 million inhabitants.

Large cities and metropolitan regions in Europe have increasingly assumed a dispersed structure and a functional dependence on advanced services (Hall, 1997). Reflecting a rapid increase in population mobility, urban sprawl in Spain began in the 1960s, determining huge expansion of several metropolitan areas (Aguilera et al., 2011). Such dynamics have been especially observed in the largest metropolitan areas of Catalonia, specifically in the regions gravitating around Madrid and Barcelona, respectively (Serra et al., 2013).

The economic structure of Catalonia is oriented toward manufacturing industry and advanced services. Although 26.7% of the total Catalan surface area is devoted to agriculture, the primary sector employs a low share of workers (3.7%). In addition to industry (53.6% of total workers active in manufacturing, construction, and chemical enterprises) and services (42.6%), tourism has had a significant role in the regional value added (IDESCAT, 2016). Based on recent data provided by IDESCAT, the Statistical Institute of Catalonia, the region is the most visited in Spain, with about 15 million foreign tourists each year).

Displaying a strong culture of regional planning (Garcia-Ramon and Albet, 2000), Catalonia has its own regional government ("Generalitat"), that has long sought to separate itself as much as possible from the Spanish administrative network. Catalonia has had a regional plan since 1932 (Rubiò and Tudurí Regional Plan), continuing with the Macià Plan (1934) and the Public Works Plan (1935). After that, a territorial plan with a remote time horizon was implemented in 1980 (Marshall, 1995), the General Spatial Planning of Catalonia (GSPC) that was approved in 1995, with the objectives of redesigning the functions of the Barcelona Metropolitan region (BMR) and balancing urban and rural areas. The GSPC defined expansion zones to reduce population pressure around the capital city (Serra et al., 2013). The largest BMR sub-centers could expand their commuting area, in order to be self-sufficient in terms of employment and services (Muñiz et al., 2003). Other areas (e.g. municipalities around the cities of Tarragona, Lleida, and Girona) were considered small

metropolitan districts with a high potential for economic growth. Coastal areas north of Girona and south-west of Tarragona were given a separate category, limiting dense urbanization to avoid traffic congestion (Marshall, 1995).

Partial Spatial Plans were approved between 2006 and 2010 with the objective to strengthen infrastructures and promote compact urban development (Nel-lo, 2011). According to the Catalan regional regulation of the Spanish National Town Planning Law, a standardization of Local Master Plans has been implemented, imposing a comparable classification of buildable land and other types of urban and non-urban land. In this way, municipal master plans refer to homogeneous land-use classes, identifying consolidated urban fabric (both residential and commercial), buildable land, and land that is undeveloped due to environmental, topographic, or socioeconomic constraints.

The BMR is made up of the central city area (divided in 10 districts) and 128 municipalities, each with its own individual social, political and economic identity (Gargiulo Morelli and Salvati 2010). In addition, topography has influenced the evolution of the RMB (Nel-lo 2001). Its current landscape derived from a history composed by sequential urban layers that combine in different development patterns (Busquets 2006; Marull et al., 2009). The RMB has witnessed a dispersive expansion resembling that of North-American suburban areas in terms of low-density residential 'sprawlscapes' (Muñoz 2003); or, on the contrary, these new urban patterns are to be valued as a mere metropolitan enlargement in which sprawl remains relatively controlled (Nel-lo 2001; Catalàn et al., 2008). By contrast, some authors argued that North American and Spanish models diverge among them: (i) urban sprawl is a relatively recent phenomenon in Spanish cities (Monclùs 2000); (ii) inner areas in Mediterranean cities have retained high population densities (e.g. Martori and Suriñach 2001; Durà-Guimerà 2003); and (iii) Spanish intensity and morphology of sprawl are different from the American model. The major socioeconomic and political variations that contributed to such rapid suburbanization process were increasing per capita incomes, changes in family structures, internal migration, developments in the communication networks and growing levels of individual mobility, the transformation of the labour market and the increasing value of housing in the dense central areas (Marull and Mallarach 2002 2005; Dura-Guimera 2003; Domene and Saurì 2007; Catalàn et al., 2008).

While assuming a polycentric structure (Dura-Guimera, 2003), urbanization in the Barcelona Metropolitan Region (BMR) has determined a mix of heterogeneous and fragmented uses of land hosting marginal economic activities that deteriorate environmental quality and have a negative impact on sustainable agricultural practices and local traditions (Garcia and Riera, 2003). The long-term evolution of the BMR reflects a latent shift from a mono-centric, dense urban structure toward a spatially balanced and functionally dispersed region (Garcia-Ramon and Albet, 2000), as a result of socioeconomic transformations typically observed in recent suburbanization phases all over Europe (Tombolini et al., 2015). More recently, early evidences for population re-densification have been observed around central cities, denoting a subtle trend towards re-urbanization and socioeconomic polarization, possibly enhanced by the global financial crisis (Carlucci et al., 2016).

The Valencian Region is located along the Mediterranean coast on the east side of the Iberian Peninsula. It consists of three provinces, which are the capital city Valencia (the third largest city and metropolitan area in Spain), Castellón and Alicante. It has 518 km of coastline on the Mediterranean Sea covering an area of 23,255 km^2, with 4.5 million inhabitants. At the local scale,

there are 534 municipalities in the Valencian Community. About 44% of the land area is used for agrarian activities, though around 52% of the Valencia Community is forested (de Paz et al., 2006). In the Comunitat Valenciana, a process of rural abandonment from the 1950s has increased the incidence of large fires from the late 1970s becoming an insistent matter (Pausas, 2004). The main existing land-use is the replacement of local species with flammable plants due to the quick recovery of the vegetation and the recurrent forest fires (Bonet and Pausas, 2007). Land-use changes from farmland abandonment led to an increase in accumulated fuel of early successional species, sustained also by the population increase in the wildland/urban interface (WUI) (Keeleyet al., 1999; Biasi et al., 2015; Duvernoy et al., 2018) and the rise in temperatures (Pausas, 2004).

2.4. Other contexts investigated

In addition to the major contexts analyzed, several European contexts, particularly along the Mediterranean area, were considered providing an effective comparison. In this way, different local areas could be analyzed among themselves (Figure 2.11). The map below shows the major European cities represented by their LUZ (Large Urban Zone).

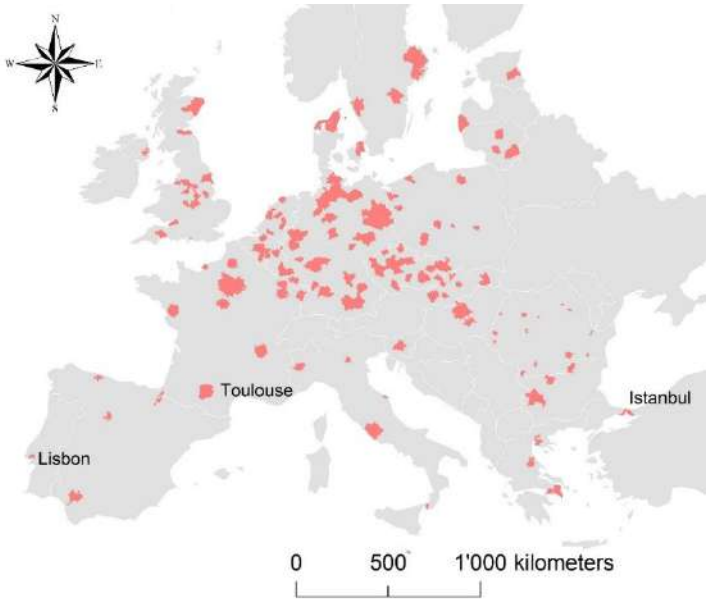


Figure 2.11. Territorial contexts analyzed in a work done in Europe.

Istanbul is the largest Turkish city since it is also an important financial and cultural center (Arslanli et al., 2006). The context has been used as an area of comparison with other European areas and covers the inner city of Istanbul with five state forest industries (Bahcekoy, Catalca, Istanbul, Kanlica and Sile), 24 rural directorates of forestry, 12 private forests (PF) (approximately 546,381 ha) and 9 islands. Istanbul is surrounded by Black Sea in the north, by the Province of Tekirdag in the west, by the Province of Kocaeli in the east and by the Province of Marmara Sea in the south. Istanbul is situated in North-western of Turkey, characterized by a dominantly smooth terrain with an average slope of 15% (Alphan 2003).

Population in Istanbul increased from 3,904,588 to 12,573,836 between 1975 and 2007, primarily due to migration (Turkish Statistic Institute 2007). The city attracted relevant migration flows during the past years as it offers many economic opportunities when compared with other Turkish cities. Istanbul has more people and industrial/commercial/activity, accounting for around 28% of Turkey's gross national product (Arslanli et al., 2006). Istanbul provides around 40% of the country's

tax revenue, is home to around 38% of the country's industrial companies around 55% of the country's commercial companies and has a current population growth rate of around 3.8% year (Cetiner et al., 1994). As a result, the urban population of Istanbul is rocketing since few decades. Due to an increase of about 10,000,000 persons (Devlet Istatistik Enstitusu (DIE) 2000; Arslanli et al., 2006), areas used for settlements have expanded in extreme proportions, both as planned urbanization and, unfortunately, illegal housing (Maktav and Erberk 2005; Aguilar 2008). Istanbul has challenged with an intensive and informal advance of residential areas since the 1950s, especially in the low-density urban fringe (Gargiulo Morelli and Salvati 2010). This kind of urbanization is consuming massive rural land and other green areas (Maktav and Erberk 2005; Aguilar 2008). Even by optimistic estimates, at least half of the IMR 12.5 million residents live in "gecekondus", a form of "self-help housing". Consequently, informal residential areas invaded new contexts, e.g. high-quality agricultural land (Bolen et al., 2007). Furthermore, land-use/land changes, affected by human-induced activities and growth population (Wear et al., 1996; Geymen and Baz 2008), is also causing land degradation and desertification of agricultural and forest areas (Montanarella 2007). The recent master plan (2007) projected new residential areas in the peripheries (IMP 2007), but also controlling urban pressure and protecting ecologically sensitive natural lands (Göksel 1998; Coskun et al., 2006; Bolen et al., 2007).

France has experienced a rapid urbanization since the early 1960s (European Environment Agency, 2006). The study elaborated by Duvernoy et al. (2018) investigated urban development and peri-urban farming in Toulouse, the fourth largest metropolitan area in France, hosting nearly 1,2 million inhabitants, one third concentrated in the central municipality of Toulouse (Zaninetti, 2006). Toulouse is the capital of the Occitanie/Pyrénées-Méditerranée region, in the South-Western France, an area has experienced important socioeconomic transformations in the last century (Martin-Brelot et al., 2010). The analysis has examined the Functional Urban Area of Toulouse (FUA) whose boundaries were defined following the Large Urban Zone (LUZ) definition introduced by Eurostat. FUAs are functional economic units identified on the base of population density and include the "inner city" (a high-density cluster of adjacent grid cells of 1 km^2, at least 1,500 inhabitants per km^2) and a (more or less extended) "commuting zone", i.e. peri-urban ring. The French FUA equivalent (i.e. urban area) - defined according to a criterion oriented toward the central-place theory - was used.

In 2010, the Toulouse metropolitan area extended on nearly 5400 km^2 of land administered by 453 municipalities (Martin-Brelot et al., 2010). The terms "Toulouse", "inner city" and "metropolitan region" respectively refer to the municipality of Toulouse, the cluster of dense municipalities concentrating the highest proportion of jobs in the region, and the Toulouse's FUA. The municipality of Toulouse is situated in the central part of the metropolitan area (Figure 2.12). The central municipality of Toulouse concentrates the densest settlements of the region (Jacquin et al., 2008). Thanks to the development of the aerospace industry (Zuliani, 2008) and advanced services (79% of working population), Toulouse has taken on an upper-rank economic role in France, although it was frequently defined a city with an "incomplete" industrial and economic structure (Jalabert, 1995).

Toulouse is one the metropolitan regions that experienced the highest population growth in France in the last 30 years (Insee, 2014). Since the late 1970s, Toulouse's urban fabric expanded rapidly into rural areas, creating a vast metropolitan region (Desbordes, 2011). Between 1999 and 2008, Toulouse metropolitan region experienced a high annual rate of growth (+1.8%), particularly

pronounced in the peri-urban ring (+3%), doubling the annual growth rate of French metropolitan regions excepting Paris (Insee Midi-Pyrénées, 2011).

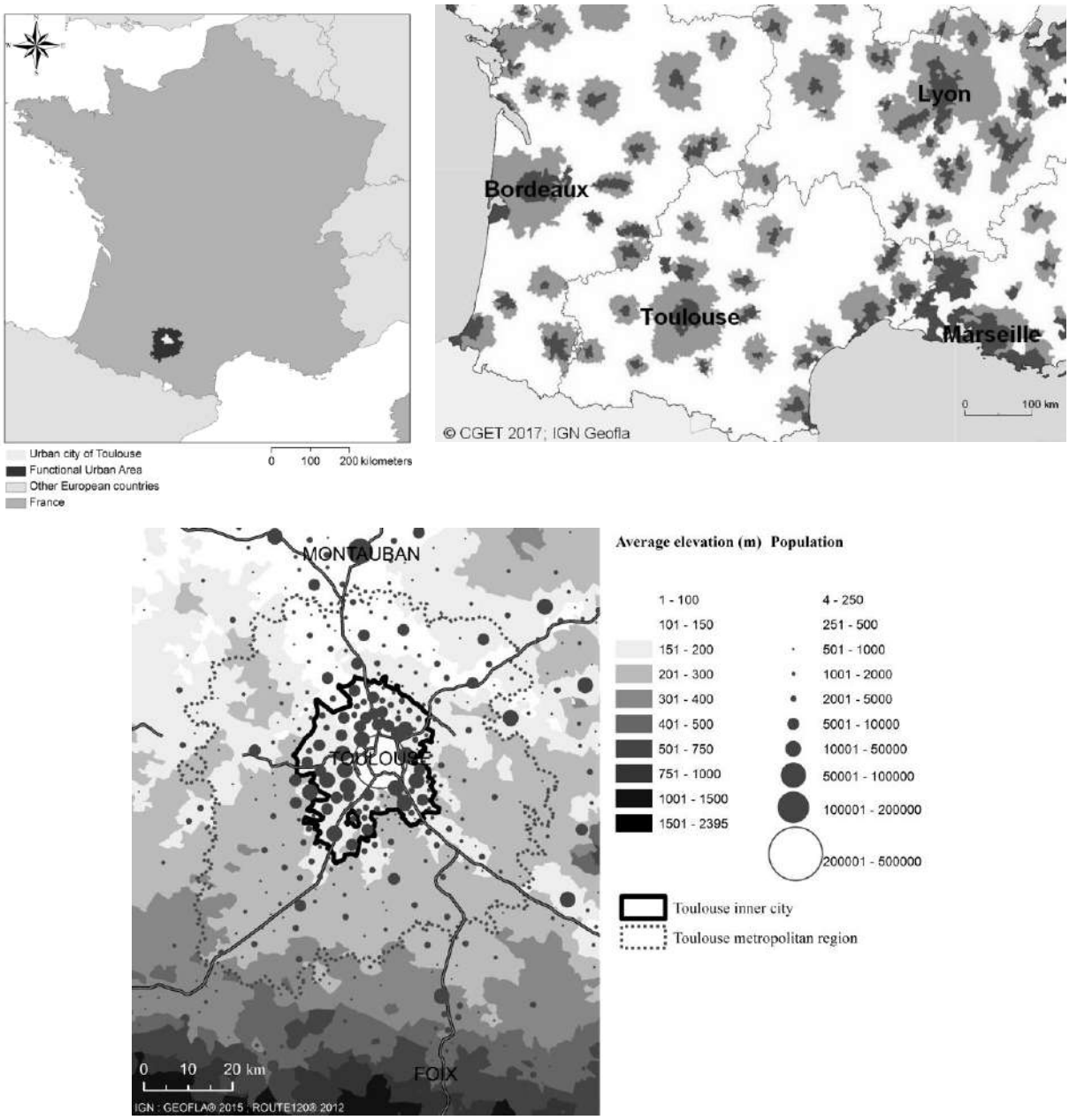


Figure 2.12. The geographical position of Toulouse in France (upper left); the main metropolitan regions in central-southern France (upper right); population density and elevation in the metropolitan region of Toulouse (lower map).

The percentage of built-up area in total landscape decreased along the Toulouse's urban gradient, consolidating disparities between dense urban areas and sparsely populated municipalities that composed the metropolitan agricultural landscape mosaic (Jacquin et al., 2008). French metropolitan regions increasingly consider agricultural activities and rural landscapes for consolidating urban food systems (Bonnefoy and Brand, 2014), providing ecosystem services and reconnecting nature and city life (Lévy and Hajek, 2016). A total of 47% of the French farms were in metropolitan regions, utilising 47% of the French agricultural land (utilised agricultural area) in 2010 (Giroux, 2015), although their production did not necessarily coincide with the specific urban demand for local food. Indeed, half of the surface of French metropolitan farms was dedicated to

arable crops (cereal, oil and protein crops) in 2010 (Giroux, 2015), a production commercialized mainly in long food supply chains as a commodity for the food industry and the livestock production. That is particularly true for the case of Toulouse metropolitan region, where municipalities propose or support initiatives for the direct supply of their citizens in organic vegetables (Duvernoy, 2016), which remain a minor production in the area, the dominant production being arable crop, cultivated by 65% of the nearly 6,000 metropolitan farms according to the 2010 agricultural census. Toulouse metropolitan area is an example of such a discrepancy between the growing demand of local municipalities for building an urban food system and metropolitan farming systems where arable crops in long food chains dominate the agricultural landscape (Duvernoy and Paradis, 2016).

Lisbon is the capital city of Portugal, with a population of about 505,526 inhabitants within its administrative boundaries, while about 2.8 million are the inhabitants of its urban area (eleventh in the European Union). This context has been used as an area of comparison with other European areas.

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3. Recent territorial configuration between demographic, socio-economic and landscape changes

3.1. Demographic dynamics, economic expansion and settlement dispersion

An intriguing debate arose in recent times around two patterns of urbanization, density and dispersion (Bruegmann, 2005; Kasanko et al., 2006; Catalàn et al., 2008; Salvati and Gargiulo Morelli, 2014). Nevertheless, only in recent decades with rapid population growth and a more awareness on conservation of natural environments, studies on centralized and compact versus discontinuous and low-density trajectories of urban development have become a matter of intense research (Aguilar, 2008; Duvernoy et al., 2018). For instance, sprawl is the typical outcome of low-density outward urban expansion (Monclùs, 2000; Nel-lo, 2001; Muñoz, 2003; Catalàn et al., 2008). Nowadays, sprawl process concerns developed and emerging countries for its negative impact on socio-ecological systems (Bruegmann, 2005).

Studying urban sprawl differs over cities since it adapts to local dynamics and structures (Bonifazi and Heins, 2002). Therefore, searching for a unique definition of sprawl is more problematic when variances in urban patterns and processes in several cities (and their metropolitan areas) located in different countries are considered (Bruegmann, 2005; Gargiulo Morelli and Salvati, 2010). Looking out for defining sprawl exploring its spatial forms, density traits, socio-economic and environmental influences exposes intrinsic complications (Chorianopoulos et al., 2010; Salvati et al., 2013b). Dispersive urban growth has brought about a change in sharpness of the density gradient line, which in the urban context moves only with an increase in population (Couch et al., 2005; Gargiulo Morelli and Salvati, 2010).

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3.1.1. Exploring urban trends in Southern Europe

Following Eurostat database, countries of the European Union comprise 511.5 million people in 2017, with an average population density of 118.3 inhabitants per km^2. Due to its ageing and low fertility rates, European population will increase moderately in future depending mainly on inward migration form countries outside the continent. Within Europe, consistent migration from East to West and from rural to urban areas still seems to be the general trend (European Commission 2004). It was predicted that the population of Europe living in urban areas will rise from 73.3% to 78.0% among 2005 and 2025 (United Nations, 2005). Consequently, urban areas will provide accommodation for 28 million additional inhabitants over the following 20 years. Besides, changing economic functions require more peripheral areas for commercial and industrial expansion, also reinforced by the competition for capital attraction amongst cities (Gargiulo Morelli and Salvati, 2010).

According to the United Nations Urbanization Prospects, by 2030, a growing pressure for urbanization will expected in Southern European and Northern African cities specifying the last year (2017) (Table 3.1). Urbanization trends have differed significantly (Bonifazi and Heins, 2002). For instance, the urbanization rate in Southern Europe has been projected to increase to 75.2% by

2030 (from 44.2% in 1950). Particularly, projections estimate 71.6% in Greece, 76.1% in Italy, 81.6% in Portugal, 82.2% in France, and 84.5% in Spain (Barbero-Sierra et al., 2013; Salvati and Forino, 2014).

Table 3.1. Urbanization rates (in percentage) for three continents and the world, 1950-2030.

Region	1950	1970	1990	2010	2030
Africa	14.7	23.1	31.8	42.7	52.9
Asia	17.4	23.4	32.3	43.0	54.1
Europe	52.4	64.6	72.1	75.1	80.5
World	29.8	36.8	43.5	51.5	60.2

Source: UN 2002.

Drivers of urban development are becoming increasingly endogenous, fed by internal redistribution, inter-urban migration and a rural exodus. Over a third of this growth will take place in the coastal regions, more specifically in the coastal cities. "Coastalisation", as the concentration of population and economic activities in the coastal spaces, represents a general trend since the last two centuries of urbanization in the Mediterranean basin (Kasanko et al., 2006; Longhi and Musolesi, 2007; Turok and Mykhnenko, 2007; Schneider and Woodcock, 2008; Salvati and Forino, 2014). As took over large hilly areas, plateaux and mountains, which characterise the inland Mediterranean area, the Mediterranean shores experienced considerable structural disabilities for urbanization purposes due to increasing international tourism (Gargiulo Morelli and Salvati, 2010; Salvati, 2014a). With 150 million tourists visiting the coastal regions, people appeal to the Mediterranean Europe as tourist destination, recording an influx could double from today until 2025 (Salvati, 2014b).

Whereas, more than half the world's population now lives in towns, two in every three residents in Mediterranean urban areas. In the coastal area in the Mediterranean basin, population went from 285 million in 1970 to 427 million in 2000, possibly reaching 524 million by 2025 giving to Blue Plan trend scenarios (Figure 3.1). Besides, urbanization rates would change from 64.3% in 2000 to 72.4% by 2025. Furthermore, the globalising economy and the consequent restructuring of the traditional rural economies and societies of the inland areas has significantly contributed to coastal urban growth in numerous Mediterranean countries (Salvati, 2014b). Trending populations and economy, coastalisation has correspondingly reinforced major works as for developing coastal plains, e.g. large-scale transport infrastructures (Kasanko et al., 2006; Salvati, 2014b).

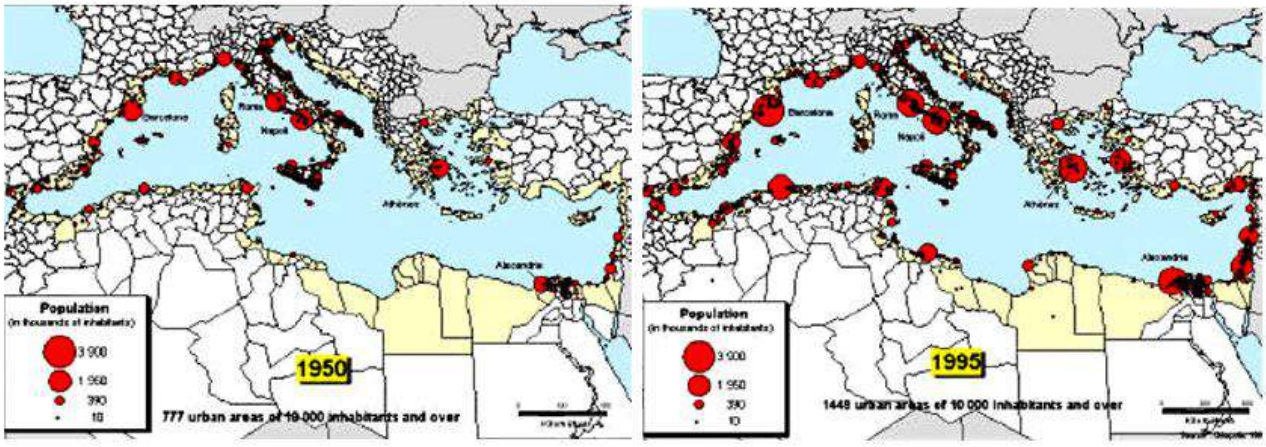


Figure 3.1. Urban areas with > 10,000 inhabitants in the Mediterranean coastal regions, 1950 and 1995. Source: Plan Bleu-Regional Diagnostic Outlook (April 2010).

Based on these premises, sprawl processes were explored in specific Mediterranean contexts (Barcelona, Istanbul, Naples). Monitoring land-use/land cover changes bring up useful information for urban planners and policy makers for the management of uncontrolled urbanization and sprawl (Alphan, 2003; Anderlini, 2003). Analysing the different degrees of urban sprawl in European cities (Newman and Thornely 1996; Bonifazi and Heins, 2002; Brezger, 2006; Longhi and Musolesi, 2007; Turok and Mykhnenko, 2007), data from the European Union's Urban Audit were used. The Urban Audit presents socio-economic and environmental statistics for 258 large and medium sized cities within the European Union city and their relative "Large Urban Zone" (LUZ). As sprawl process arises beyond urban boundaries, the adoption of different spatial urban extension should include all those areas inhabited by daily commuters. Therefore, using LUZ data rather than cities outcomes chiefly convenient for investigate dispersive dynamics. However, some caution must be used in using and interpreting this data: for instance, the administrative boundaries of LUZ do not automatically coincide with the functional and political ones (Couch et al., 2008; Gargiulo Morelli and Salvati, 2010). Furthermore, such informative arrangement was mainly useful for analyzing sprawl as a process which differs from urban growth, expressing how the density gradient line diverges over time. In fact, sprawl occurs when the percentage of the population living in the core city declines relative to the total population of the conurbation (Couch et al., 2005; Turok and Mykhnenko, 2007). Cities can be generally classified in four types according to their growth and sprawl trends (Antrop, 2004). Firstly, urban containment appeared, commonly in Northern cities of Europe which successfully combat sprawl. They are consistently growing and achieving greater compaction at the same time. Secondly, urban growing rates are combined with sprawl, mostly common trend in most European cities. Dutch cities seem to combine quite high rates of growth with strong restraints of sprawl. Thirdly, negative increasing rates accompanied by a greater compaction or negligible sprawling rates. This group is probably the smallest. And finally, a decline in population is combined with consistent sprawling rates. This is the group of cities which are experiencing the worst organization in urban planning.

3.1.2. Urban diversity in the Mediterranean basin

Sprawl processes were studied in three Mediterranean contexts: Barcelona in Spain, Istanbul in Turkey and Naples in Italy. Population distribution in the Barcelona Metropolitan region (BMR) is different from others in Europe (e.g. Nel-lo, 2001). The most important changes have occurred in the subcenters around the central city. After two decades (1960-1980) of strong immigration from the rural areas of south Spain, the population of Barcelona municipality grew from 1,557,863 to 1,754,900; while, for eleven municipalities around the central city the population grew much more, passing from 571,088 to 1,413,603. The absence of some planning system in these years had a special effect for the population distribution. The urban structure is irregular where population is concentrated in small areas. The outcome of such suburbanization combines high-density areas within a large industrial area.

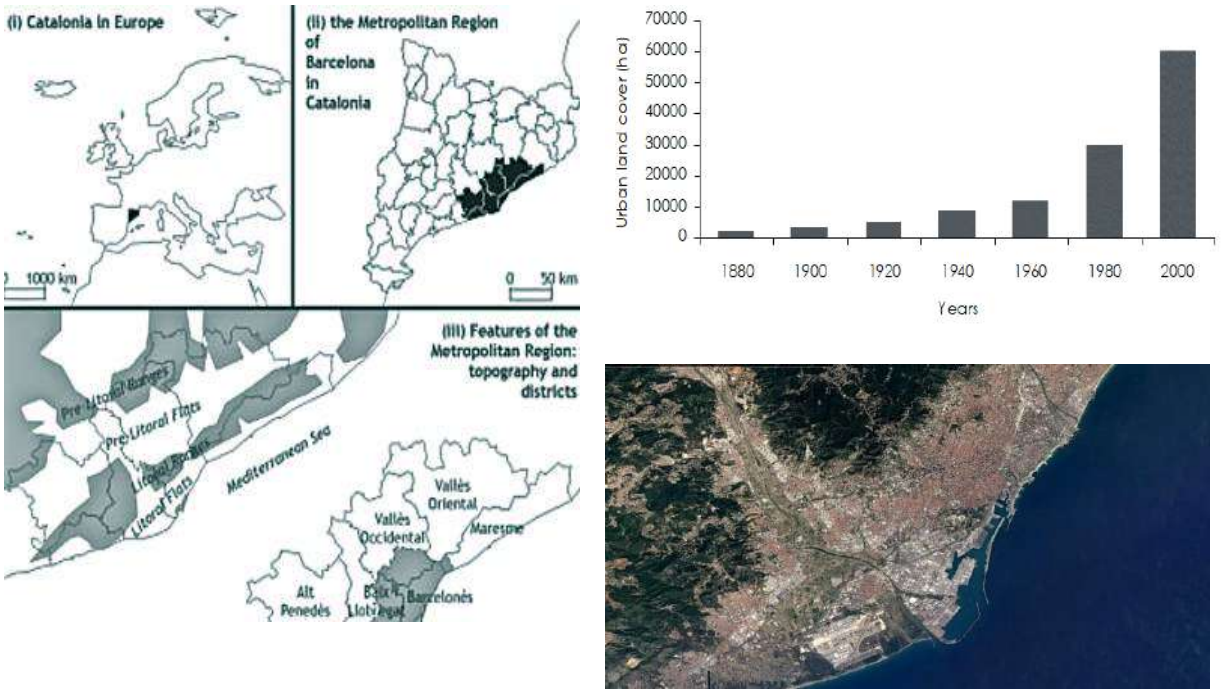


Figure 3.2. (left) Location map and main features of the BMR (Source: Departament de Geografia Fìsica i Anàlisi Geogràfica Regional, Universitat de Barcelona, Catalonia, Spain); (upper right); evolution of built-up land-use in the BMR, 1880 - 2000 (Source: Catalàn et al., 2007); (lower right) a digital picture of inner Barcelona from Google Earth imagery (2016).

Since the 1950s, the BMR has experienced an accelerated process of land occupation (Figure 3.3). Between 1950 and 1975, entire new neighborhoods were built at the edge of traditional cities to accommodate the increasing population migrating from rural areas to the city in a process like that of Italy. From 1975 onwards, migration flows tended to stabilize, but the residential dispersion continued and even increased. Between the 1975 and 1986 and coinciding with a period of economic recession in Spain, urban growth remained fairly-low. Land occupation receded, but residential decentralization was sustained through infilling processes of former urban "islands". Many of the second homes built during the previous period became main residences consolidating thus the dispersed urban model. In 1986, the economy began to recover together a new wave of land occupation for urban purposes in the metropolitan peripheries that took off during the 1990s. The evolution of the average density per territorial unit illustrated the existence of the suburbanization course and the population shift towards the BMR periphery (Figure 3.3).

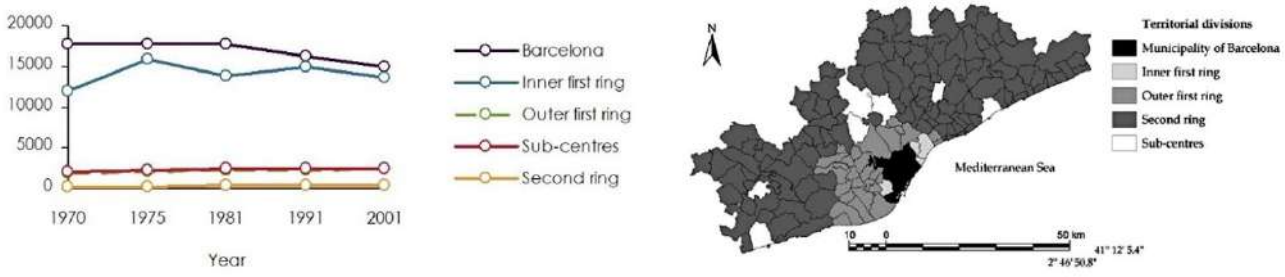


Figure 3.3. Evolution of population densities in the different territorial divisions of BMR

A general survey of land-use for the BMR for 1994 and 2001 is given back in Table 3.2. Several key trends become apparent. First, the total area of cropland has declined significantly during this period, while the area of urban land has gradually increased. Forest land has remained relatively stable across the region. However, trends are not uniform across the metropolitan region. Indeed, urban expansion appears to be more rapid in some districts (e.g. Garraf and Baix Llobregat) than others. Similarly, forestry areas have clearly expanded in districts like Alt Penedès but not in some of the others. Also, urban land has not increased uniformly amongst the districts.

Table 3.2. Land-use (%) in the BMR for 1994 and 2001.

District	1994				2001			
	Forest	Cropland	Urban	Other	Forest	Cropland	Urban	Other
Alt Penedès	39.31	52.11	8.36	0.22	47.20	39.57	7.19	6.05
Baix Llobregat	46.85	23.52	29.19	0.44	39.94	11.18	45.73	3.15
Barcelonès	11.75	4.47	83.5	0.28	17.13	2.40	79.20	1.27
Garraf	65.94	23.53	10.28	0.25	57.03	11.36	17.76	13.85
Maresme	52.54	26.63	20.32	0.52	56.21	12.51	25.39	5.88
Vallès Occidental	55.27	19.66	24.85	0.22	58.27	9.4	31.51	0.83
Vallès Oriental	67.56	19.06	12.89	0.49	67.37	13.15	15.61	3.86
Total region	52.67	26.42	20.54	0.37	53.74	16.36	25.59	4.31

Source: Elaborated from Estadìstiques agràries i pesqueres de Catalunya. Departament d'Agricultura, Ramaderia i Pesca.

The largest increases are particularly observed in the sub-centers and in the municipalities of the external part of the first metropolitan ring which appears to confirm the assertion about the importance of the existing urban fabric in the sprawl processes of Southern European cities. In the BMR, between 1994 and 2000, crop land recorded the largest decrease, confirming its role as repository for urban growth. Relatively large and flat areas and proximity to urban settings explained its proclivity to fall under the advance of urbanization. Shrub land and other non-urban land cover fall, whereas forest land exposed the lowest decrease between 1994 and 2001. The first periphery registered the highest non-urban decrease, with an inner part having already a low non-urban area, and an outer part suffering important loss. In contrast, the second periphery experienced the lowest non-urban decrease because of its high initial non-urban area and its meagre urban potential. The wide-ranging trend for the whole BMR pointed out an outward expansion with the most rapid growth occurring on the fringe. However, this development has not spread outward in simple concentric rings: between 1956 and 1972, it was discontinuous with the most evident pattern being the formation of separated islands or patches of urban development in the fringe areas. Urban sprawl in Barcelona seems to have adopted leapfrog development and conversion of second houses into main ones as the principle modalities of manifestation.

Only in the successive period (1973-2002), urban expansion concentrated along major roads in the areas between the urban center of Barcelona and some urban islands on the fringe. Much of the new development on the fringe of Barcelona consists of low-density detached housing. 40% of new houses in the central areas of the BMR were detached family houses, while in the small towns and villages of the rural-urban fringe, 70% of new houses were detached (Muñoz 2003). Such proliferation of detached housing contributed to drive urban sprawl as favored housing type for many residents. Furthermore, non-urban land prices are relatively low, making housing more affordable.

In addition to the dispersive residential phenomenon, the construction of second homes in Barcelona was emblematic. In the 1960s and 1970s, several people living in Barcelona purchased second homes in the rural-urban fringe, often in hilly or mountainous areas. Indeed, the Litoral and Pre-litoral ranges were occupied by hundreds of small plots, most of which were simply a result of the subdivision of an unproductive farm. While, many of these new settlements were only occupied during holidays or weekends (or even permanently unoccupied); by the 1990s, they had become an important part of the expansion of the metropolitan region as people began to convert them to permanent homes. These new types of settlements, called "urbanitzacions" in Catalan, are now more than 800 in the BMR occupying a total of 22,000 ha, which constitutes approximately 40% of the 50,000 ha of designated urban land in the region. Morphologically, these areas seem 'islands', due to their only one access route, and embody a form of 'leapfrog' development, quite different from a contiguous form of urban expansion.

Together with residential expansion, also the relocation of industrial activities occurred in peripherical areas. Several industries shifted from the central areas of Barcelona to the outer well-connected areas of the metropolitan region, particularly in the Baix Llobregat and Vallès districts. Two of the most important land-uses along the main transport routes in these areas are logistics and freight activities, both of which require large amounts of space. In the Alt Penedès district, relatively low land prices contributed to the most recent wave of industrial occupation. Even an increase in retailing activities and shopping centers sprung up in areas that offer cheap land with easy access to transport networks. The first of these major shopping centers was the Baricentro in 1980, constructed at the junction of the Mediterranean and the Barcelona-Sabadell Highways. More recently, large shopping centers were constructed on other major transport routes (e.g. the Maresme Highway and L'Ametlla Highway).

Environmentally, sprawl contributed to a significant decrease of agrarian land in the fringe. Between 1972 and 1999, cropland fell from 80,000 to 50,000 ha (- 36%), especially around central Barcelona and in Maresme, Vallès Occidental and Baix Llobregat districts, with average reductions of between 75 and 100%. The most rapid decrease occurred between 1982 and 1989 (- 20%), and between 1989 and 1999 (- 12%). In 1999, cropland in most municipalities near Barcelona represented less than 10% of total land-use while, in some fringe and flat areas, cropland still uses more than 50% of the total. Agrarian land-use change has been coupled by significant changes in forest land. Data from the National Forestry Inventory indicated that forest use in provincial Barcelona increased from 362,000 in the mid-1960s to 424,186 ha in the mid-1980s. Between 1994 and 2001, the growth was only 1% according to data from the Department of Agriculture. Forest cover in the lower lying areas has remained relatively stable thank to natural parks and other protected spaces in mountainous areas. In mountainous areas, farming tended to be marginal, shifting towards an afforestation. Preserving and enhancing Barcelona's natural environment through natural parks, forestry has not diminished.

In the BMR, the current urban saturation of the metropolitan inner core limits future urban growth (e.g. Gargiulo Morelli and Salvati, 2010). Subcenters and municipalities located in the outer part of the first periphery have taken over the urban expansion. Subcenters have a significant historical background and considerable high urban densities; while, the other municipalities offer affordable housing prices and more modest densities. Both attract people searching for their first

home or for better standards of life that have left the most compact and central part of the BMR (Busquets, 2006).

Municipalities of the first periphery have the benefits of their centrality and proximity to Barcelona, enjoying the greatest urban potential and experiencing the highest relative urban gains. Changing development model towards urban sprawl is tangible in the BMR, mainly in its peripheries (Catalàn et al., 2008). Wide-ranging land occupation, high agricultural and forest and the decrease in urban densities expecting for further development are some signs of the current urban transformation (e.g. Gargiulo Morelli and Salvati, 2010; Serra et al., 2014).

The demographics of Istanbul changed considerably between 1927 and 2000 (Table 3.3). The population of Istanbul has grown 12.4 times of its initial population by increasing to 10,018,735 in 2000 and consequently the number of persons per km^2 of the region significantly increased, reaching values of 1,7000 in the year 2000. During 1990-2000 periods, for instance, the annual population growth rate of Istanbul was 33.1%. Until 1980, this rate in the countryside was higher than that of the city due to the higher migration to the rural areas in Istanbul. In 2000, however, the share of population living in Istanbul was 90.7%. The rapid change in the proportions of the populations of city and village occurred in the '80s due to the new arrangement in administrational division structure of the Province of Istanbul.

Table 3.3. Demographic change in Istanbul metropolitan region (IMR).

Years	Urban	Rural	Total	Urban (%)	Rural (%)
1927	704,825	102,038	806,863	87.35	12.65
1940	815,638	175,599	991,237	82.28	17.72
1960	1,506,040	376,052	1,882,092	80.02	19.98
1980	2,909,455	1,832,435	4,741,890	61.36	38.64
2000	9,086,599	933,136	10,018,735	90.69	9.31

Source: State Institute of Statistics of Turkey.

In the last 80 years, Turkey has faced rapid changes in its spatial organizations given the changes in agriculture and industry. Besides Istanbul, changes are well observed on every corner of the country's agricultural landscape and mainly in several urban spaces like Ankara, Izmir, Iskendrun and Adana.

With rapid economic development, the standard of living has considerably improved over the last decades besides environmental degradation. A direct relationship has been observed between land-use changes detected via satellite images and socio-economic improvement of the region.

According to the outcomes obtained from the classified images dated 1990 and 2005, the distribution of the built-up areas was 11 and 16%, while croplands accounted to 27 and 23% of the total area. Forest areas covered 25% of the total area in 1990 and 2005, indicating that such areas were under strict control and were conserved. In the change detection analysis, a comparatively more significant variation in land cover has occurred between years 1990 - 2005. Values of the urban expansions for the period of 1990 -2000 and 1995 - 2005 were calculated as 10,821 and 16,727 ha. Between years 1990-2000, the urban expansion rate reached 18% although, during the 1995-2005, it was 24%. These increments mainly occurred in the areas, near the highway, airport and the coastline. Another significant change was the continuous decline in croplands. Particularly, the decline of croplands mainly occurred far from the center of the districts prior to 2000 and 2005. They decreased from 144,775 to 144,230 ha during the periods of 1990 - 2000 and 139,392 to 126,339 ha during the

period of 1995 - 2005. The overwhelming influx of internal migrants from mainly eastern part of the country informally or/and illegally occupied the land at the outskirts of several major cities. With its uncontrolled population dynamics, Istanbul has later turned out to be one of the well-known primates and largest cities in the world.

By analyzing demographic change and transformation of land-use patterns, intensive migration and natural population growth in Istanbul caused continuous urban expansion. Also, a decrease or total loss of forests and agriculture fields went off a rapid increase of building activities, determinable through the analysis of GeoCover satellite images. Industrialized areas, which did not exist in 1984, have been extended due to planned building, highway and sea connections in the district (Terzi and Bolen, 2009). Neighborhoods were intensively (or more slowly) developing in the following periods.

Neighborhoods with transition characteristics turned into compact areas due to population density increase. Low-density dispersion affected spatial development in the IMR, turning into a compact shape due to growing density and\or evolving new subcenters. The past master plans proposed new housing development areas in the periphery, nonetheless sprawl has promoted and stimulated compact neighborhoods in the following period. The 10% of total population lived in 35% of total urban areas with gross density of 423 person/ha in 2005; while, 21% of population lived in more than half of urban area with gross density of 45 person/ha. By analyzing its development patterns, the IMR has expanded since 1975, following a compactness in the following period. A neighborhood that once sprawled has later turned into compact due to rising density and\or emerging new subcenters near to it. Urban decentralization, determined by market forces and Master Plans, were unavoidable, especially under the settings of rapid urban population growth.

The 142 Municipalities of the metropolitan region of Naples (MRN) can be divided in 6 concentric belts (Figure 3.4). Results exposed how population trends varied over time in these belts, following census data taken over the period beginning in 1861 to 2009 (Figure 3.5). Population loss has spread in its surrounding municipalities, especially in areas of the first and second belt. On the percentage of total population in each belt, Naples grew until 1921 (approximately 45% of the total population was living in the city), while the percentage of residents in the external municipalities decreased. Since 1921, demographic trend has been reversed and, in 2009, Naples residents are about 24% of the total population of the MRN, a similar percentage to the population of the first belt (23%). Even the areas of the second, third and fourth belt have had increasing rates, and have reached values of 15 to 17% in 2009. A consistent population growth between 1936 and 1981 occurred where inhabitants nearly doubled in that period, passing from approximately 2,178,000 to 3,700,000. In the following years (from 1981 to 2009), the rate of population growth has clearly decreased. Since 1961, Naples has progressively lost population while the areas of the first to fourth belt have seen a continuous increasing trend.

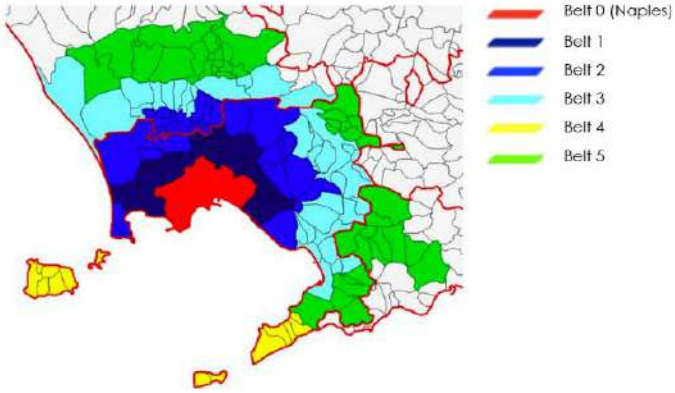
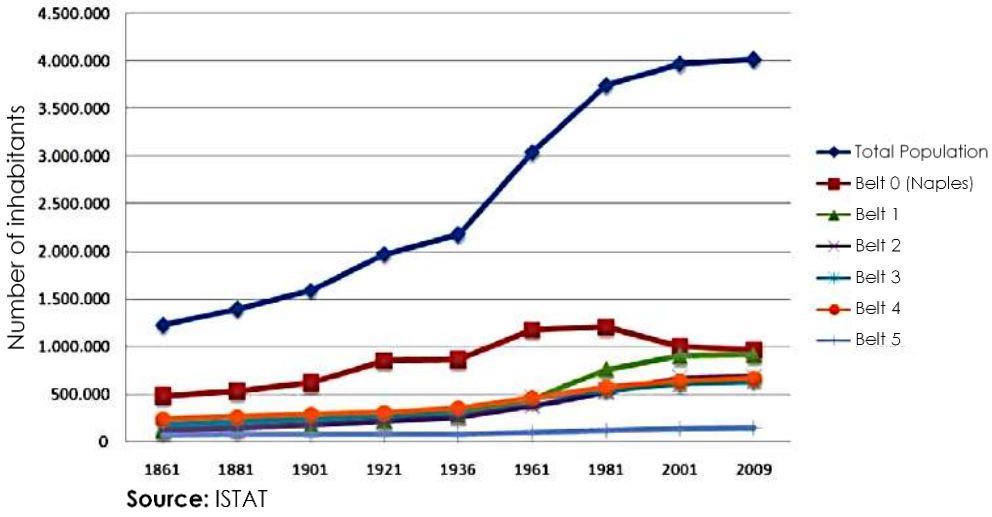
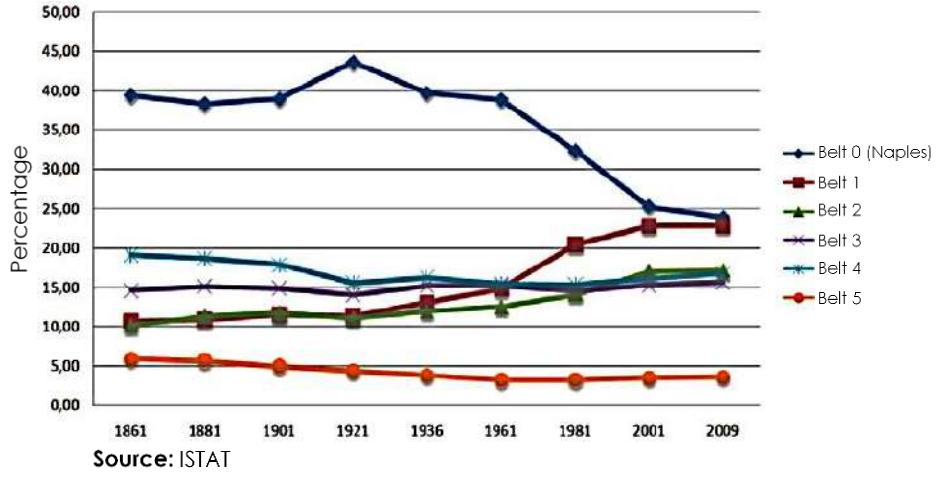


Figure 3.4. Municipalities of the Metropolitan area of Naples divided in 6 concentric belts.



(a)



(b)

Figure 3.5. Population trend for the Metropolitan area of Naples (a) and population percentage trend for the Metropolitan area of Naples (b).

The analysis brings out an interesting result: Naples is having difficulty in retaining population due to the deterioration of its urban environment and to the constant high costs for housing in the

area. Consequently, flows of internal migration have occurred in the MRN, resulting in a decrease of population density throughout the entire region with a growing decentralization urban use.

3.1.3. Contrasting patterns of growth and change in metropolitan regions

Urban growth can be defined as a complex and dynamic process related to landscape transformation driving forces with different nature (e.g. political and environmental) that affect city and recently also its metropolitan area, at several spatio-temporal scales (Jomaa et al., 2008; Jaret et al., 2009; Akin et al., 2014). Change recognition of land cover and land-use is an overbearing contribution for planning, monitoring, management and studying urbanization and landscape dynamics, environmental impacts, natural hazards and other risks (European Commission 1998; Serra et al., 2003; Sanli et al., 2008; Schneider and Woodcock 2008; Travisi et al., 2010). New urban features determined new deals counting unplanned population growth, decreased forested areas, increasing pollution, land fragmentation and erosion (Kucukmehmetoglu and Geymen 2009; Ayazli et al., 2015). In the three studies cities, dispersive urban growth threatens the most vital natural areas and fragile ecosystems, especially geologically risky areas (Ayazli et al., 2015).

With regards to the population development of the BMR, distribution and growth has been unequal since the 1960s. Between the 1960s and 1980s, a period of intense migration flows from rural to urban areas, the central metropolitan zone witnessed an increase of approximately 200,000 people (from 1,557,863 to 1,754,900), while in the surrounding areas the increase was much more significant (from 571,088 to 1,413,603). In fact, urban development markedly increased in the surrounding areas of the central city, given birth to several Subcenters (urban islands), some of which were the result of illegal building activities. Towards the end of the 1970s, population growth and migration flows in the BMR had stabilized. Nevertheless, residential dispersion continued, especially over areas in between former urban islands and along major transport infrastructure works. This has probably been the consequence of growing costs of the compact city, the urban land market and the congestion of the urban center (Burchell et al., 2005; Busquets, 2006). Above all, the gradual saturation of the metropolitan inner core together with the low densities and housing prices of the periphery acted as push factors to the sprawl process that was gaining strength by the 1980s. Furthermore, public investment for infrastructure development contributed to the conversion of second homes (located in the urban fringe where land was cheapest) to main ones, again nurturing the residential dispersion of those years. Through stagnant population for the whole BMR since the early 1980s (Catalan et al., 2008), other factors interplayed towards the peripheral outer fringe, such as urban land market and further urban costs e.g. congestion (Garcia and Riera, 2003).

Because of the history of urbanization of the second half of the 20th century, the BMR's landscape is the result of the overlapping of successive urban layers (Marull et al., 2009). Findings evidenced that major land-use changes between 1994-2001 have occurred for cropland (a decrease from 26.42% to 16.36%) and urban land (an increase from 20.54% to 25.59%). The largest increase in urban land has occurred in Subcenters and municipalities of the external part of the city, mostly at the expense of agricultural land.

The observed overall trend of urban land-use change testifies an outward expansion of the metropolitan area. Discontinuous urban growth and ribbon development are the dominant spatial patterns of the sprawl process in the BMR (Paül and Tonts, 2005; Catalàn et al., 2008). The relating causes are the rising level of car ownership, the relocation of industrial and retailing activities to the

urban fringe, infrastructure development and the conversion of second homes (located in the metropolitan periphery) to main ones in the 1990s. Therefore, agricultural land has mainly decreased in the fringe around the central area of Barcelona). To sum up, fringe land urbanization, loss of agricultural land in the periphery and decreasing urban densities of the inner core of the BMR are all signs of an evident switch to sprawl patterns of development.

The second case-study is dedicated to the assessment of dynamics of the sprawl process in the IMR (Terzi and Bolen, 2009). With intense population growth in capital of Turkey since the 1980s, an intense period of urbanization has begun. In Istanbul, residential areas have extended by around thousand ha per year, at the disadvantage of semi-natural vegetations, forests and rural crops (Kaya and Curan, 2006; Kucukmehmetoglu and Geymen, 2009). Above all, built-up areas were mostly the consequence of illegal and spontaneous housing activities ("gecekondus"), that consumed most of the agricultural land of surrounding urban areas. Such phenomenon was further scaled-up by infrastructure development, that allowed easier access to the city where most people work. By the end of the 1980s, Istanbul started to decline because of the formation of various subcenters in the urban fringe. Furthermore, multi-center development had been encouraged by the Master Plan of 1980. Urban expansion was later fueled also by economic growth of the city and the appearance of new commercial activities.

With regards to population growth, data suggest that between 1927 and 2000 the total inhabitants of the IMR have increased more than 12.4 times. Therefore, population density in the area is high. Land-use changes were detected through satellite remote sensing techniques for the period 1990-2005. The analysis focused on the evolution of built-up areas within and around the central city. The data collected exhibited an increase of 5% of built-up areas (from 11 to 16%), a decrease 4% of agricultural land (from 27 to 23%) and a rather constant trend for forest areas (from 28.4 to 27.5%). For the last ten years (1995-2005), urbanization rates were calculated to be around 24%, mainly next to highways (the E-5 and Transit European Motorway), coastline and the airport.

Assessing urban sprawl in the IMR, due to the impressive population increase of the last 30 years combined with strong economic development and the arrival of new commercial activities, areas used for settlement expanded (mostly following illegal housing) consuming agricultural and forested land (Çakir et al., 2008; Terzi and Bolen, 2009; Salvati and Gargiulo Morelli, 2014). So, uncontrolled planning has resulted in the extension of urbanization and loss of agricultural land (Alphan, 2003).

Based on demographic and land-use changes data, a sprawl index was calculated for each neighborhood for the period 1975-2005. Residential areas with low values of the index indicated an intense sprawl process, while high values referred to compacting neighborhoods. Finally, results mapped to give a clear view on the urban dynamics of the IMR. The outcomes obtained evidenced a peculiar pattern of development. The intense urban expansion of the 1980s towards the peripheries of the central city was contrasted by an opposite trend in the following period. In other words, most of the neighborhoods of the urban fringe that were once sprawling are now compacting. This was the consequence of a growing population, market forces, Master Plans and the emergence of new subcenters. In conclusion, an urban decentralization process was at work in the IMR. Even if compact developments are following the sprawl process of the 1980s, the IMR still presents the

typical characteristics of urban sprawl; however, it is premature to speak of urban growth rather than sprawl in the IMR.

Findings underlined the importance of understanding urban changes as a precondition for the design of measures of sprawl. The analysis benefits the assessment of the impacts of spatial variables, e.g. density, distance to centers and strength of centers, on urban form and how they are determined by sprawl dynamic forces. Urban sprawl should be comprehended as phenomenon and even be measured for the future development planning in the IMR (Terzi and Bolen, 2009; Kucukmehmetoglu and Geymen, 2009). Monitoring land-use/land changes aims at providing useful information for urban planners and policy makers for the management of uncontrolled urbanization and sprawl (Anderlini, 2003; Karaman, 2008).

The third narrative case-study in the Metropolitan Region of Naples (MRN) focused on sprawl process. Due to the lack of a robust planning system, the mentality of "dispensation" of the population and the permissive building code, several cities (especially Naples) have chaotic, inefficient and unsustainable patterns of urbanization (Papa and Mazzeo, 2014; Pili et al., 2017). Even along the administrative limits of the city, the disordered urban continuum can be observed, which leaves no space for different identities in which an unclear built environment is composed of several objects thrown together (Amato 2016). The periphery of Naples is not an indistinguishable area; however, it can be divided into four typologies: the ancient rural centers; the suburbs of quality districts where the bourgeoisie emigrated from the urban center; zoning area of public housing; and then recently built-up areas of public housing but completely degraded (Amato, 2008).

Today, from North to East the region is characterized by an undifferentiated, homogeneous and over-urbanized space (Gargiulo Morelli and Salvati, 2010). The conversion of agricultural land to vast areas of impervious surface has been a common reality for the MRN since the 1950s. But to be sure that such phenomenon is related to urban sprawl and not urban growth, demographic data and population distribution over land was analyzed. Between 1936-1981, total population in the MRN almost doubled (from 2,178,00 to 3,700,000). Since 1981 rates of population growth have significantly decreased while the central area of Naples began to lose population since 1961. The population growth of the central city (Naples) grew until 1921, reaching 45% of the total inhabitants of the MRN. The total population is almost equally distributed over all the territory of the MRN: 24% in the central city, 23% in the first ring belt and 15 to 17% in the remaining ones. To put it briefly, residential densities in the inner core of the MRN have significantly decreased, and the total population fallouts almost equally dispersed over the entire region.

A comparative analysis of land-use and urbanization patterns and processes may shed light on (more or less) intense urban transformations leading to important changes in metropolitan structures and socioeconomic configurations. An integrated framework, linking quantitative analysis with a narrative approach may better evidence complexity in land-use transformations and suggest specific solutions for sustainable land management linking social cohesion, environmental sustainability and local competitiveness.

3.2. Revisiting "Southern" sprawl

Dispersed urban expansion, a phenomenon known worldwide with the term 'urban sprawl', determines changes in both urban patterns (e.g. settlement morphology and urban form) and processes (spatial distribution of economic functions, socio-spatial disparities, political and cultural factors consolidating the role of peri-urban areas). Physical elements related to space, have been extensively evaluated in order to analyze how sprawl has manifested and taken place in metropolitan regions (Southworth and Owens, 1993; Tsai, 2005; Kazepov, 2005; Couch et al., 2007). Urban sprawl would be possible under a variety of political, economic and cultural conditions which manifested itself worldwide (Galster et al., 2001; Frenkel and Ashkenazi, 2008). Sprawl is identifiable in suburban areas where low-density residential settlements have progressively replaced the traditional agricultural and forest mosaic leading to a mixed and undefined landscape, disseminated of detached family houses, where population is highly dependent on private transport (Ewing et al., 2002; Tsai, 2005; Torrens, 2008). The main causes of sprawl can be envisaged in (i) a complex system of interacting agents at the base of the dispersed expansion of cities and metropolitan regions (Gargiulo Morelli and Salvati, 2010); (ii) lack of efficient planning systems at the regional scale and, more frequently, at the urban scale (Gibelli and Salzano, 2006); (iii) a generalized misuse of non-urban land determined by policies regulating cities' growth and the development of peri-urban regions (Giannakourou, 2005).

Cited article

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Sprawl can be thus considered an intriguing spatial model involving social, economic and environmental issues and reflecting the interplay between urban patterns and development processes (Galster et al., 2001; Frenkel and Ashkenazi, 2008; Orenstein et al., 2013). Since sprawl is based on several interacting factors, it is difficult to understand how urban dispersion is structured over time and scale (Kazepov, 2005; Couch et al., 2007; Cassier and Kesteloot, 2012), making complex to implement appropriate strategies of urban containment and sustainable land-use management policies (Bruegmann, 2005; Hall and Pain, 2006; Angel et al., 2011). From these premises, sprawl appears to be a key issue for contemporary cities, due to the overpowering degree of laissez-faire policies (Costa et al., 1991).

Southern Europe is an interesting case for studying the impact of dispersed urban expansion on different city development models. The spread of low-density settlements from inner cities to suburban areas is a traditional phenomenon for North American cities observed since the beginning of the twentieth century (e.g. Duany et al., 2000; Bruegmann, 2005). By contrast, sprawl can be identified as an untraditional, and possibly more recent, development model for some European cities, especially those situated in the Mediterranean Europe (European Environment Agency, 2006; Kasanko et al., 2006; Couch et al., 2007). From the 1970s, urban dispersion advanced rapidly in European Mediterranean cities, with urbanization rates growing much faster than population. This trend was observed in Barcelona (Catalán et al., 2008), Marseilles and the nearby Rhone valley (Pinson and Thomann, 2001), Rome (Munafò et al., 2010) and Athens (Salvati et al., 2013a), among others. The diffusion of sparse settlements driven by population de-concentration since the early 1980s has created a mixed landscape around the main cities and is considered a relevant

socioeconomic challenge in the Mediterranean region (Alphan, 2003; Catalán et al., 2008; Terzi and Bolen, 2009; Salvati and Sabbi, 2011). According to the projections proposed by United Nations Urbanization Prospects (derived from the web site esa.un.org), urban population will be 72% in Greece, 76% in Italy, 82% in Portugal and France, and 85% in Spain by 2030.

The key words emerging from rapidly-changing local contexts are diversification, entropy and isolation, among others (Burgel, 2004). Contemporary cities in southern Europe take on a polarized spatial structure emphasizing population disparities (Delladetsima, 2006; Leontidou et al., 2007). The economic space became fragmented assuming a spatial organization hardly classifiable as 'polycentric' (Giannakourou, 2005; Maloutas, 2007) and with relevant services and infrastructural divides at the local scale (Leontidou, 1990; Krumholtz, 1992). Long-term trajectories in Mediterranean urbanization - supposedly converging at the regional scale - contrast with patterns and trends in urban expansion which are characteristics of each country and possibly of each city investigated.

An interpretation of 'southern' urbanization with less common aspects and more differences at the regional scale was proposed. Sprawl is intended as a recent urbanization pattern exemplificative of this challenge, moving from a unifying 'Mediterranean' vision to city-specific 'growth and change' processes better characterizing the southern European urban arena (Kasanko et al., 2006). The cases of Barcelona, Rome and Athens are considered in the present study. These cities share similar territorial characters, showing a unique urban structure and socioeconomic configuration. Sprawl has adapted to their contexts in different ways depending on historical, cultural and political issues. Exhibiting a regional or national capital role, these cities have hosted competitive events of global importance, such as in the case of Athens and Barcelona with the Olympic Games. A narrative comparison of the recent processes of urban growth reveals how sprawl has occurred at the metropolitan scale and the apparent and latent connections between compact urbanization, land-use and economic structure observed in the three cities. By integrating narrative and quantitative approaches elements to 'reset' the scene of 'southern' sprawl were provided revisiting the main socioeconomic drivers of change in contemporary Mediterranean cities.

3.2.1. A comparative analysis of the socioeconomic context

Together with the difficulty in analyzing patterns and processes of dispersed urban expansion from the socioeconomic point of view, there is a lack of basic information required to perform this type of analysis at a spatially disaggregated geographical scale. The absence of unifying databases containing homogeneous and relevant diachronic information complicates the comparison between metropolitan areas when identifying different types of sprawl patterns and processes. A comprehensive picture of the recent development of Barcelona, Rome and Athens was proposed based on a set of contextual indicators with the aim to assess a variety of socioeconomic issues related with sprawl. A narrative approach was based on the simplified analysis of maps and the spatial distribution of indicators derived from official statistics and other data sources, integrated with a bibliographic analysis of recent publications in the field of urban studies in Europe - and especially in southern Europe. Local administrative boundaries (namely the NUTS-5 level of the European Territorial Classification of Statistical Units) were used as the elementary spatial domain of analysis.

3.2.2. The intimate land-use pattern of sprawl

Data on the total surface of the three metropolitan areas and population density are provided in Table 3.4 using information derived from the Urban Atlas, an initiative of the European Environment Agency producing high-resolution land-use maps scaled 1:10,000 for several metropolitan areas, and official statistics. Metropolitan areas were identified using commuting data from the most recent population census. Land-use maps were elaborated using a nomenclature based on three classes: (i) built-up areas, (ii) cropland and non-forest natural areas and (iii) forests (Figure 3.6). The three cities show different morphologies: compact settlements in Athens, semi-dense and discontinuous settlements in Rome and a more aggregated and spatially-balanced urban fabric in Barcelona. A landscape metric (perimeter-to-area ratio) was finally calculated for each land patch and mapped to identify urban districts with higher land fragmentation.

Table 3.4 Surface area (km^2), population and density (inhab/km^2) in the three metropolitan areas.

City	Surface area (km^2)	Population	Population density (inhab/km^2)
Barcelona	3242	4,394,412	1355
Rome	5352	3,700,424	691
Athens	3025	3,724,393	1231

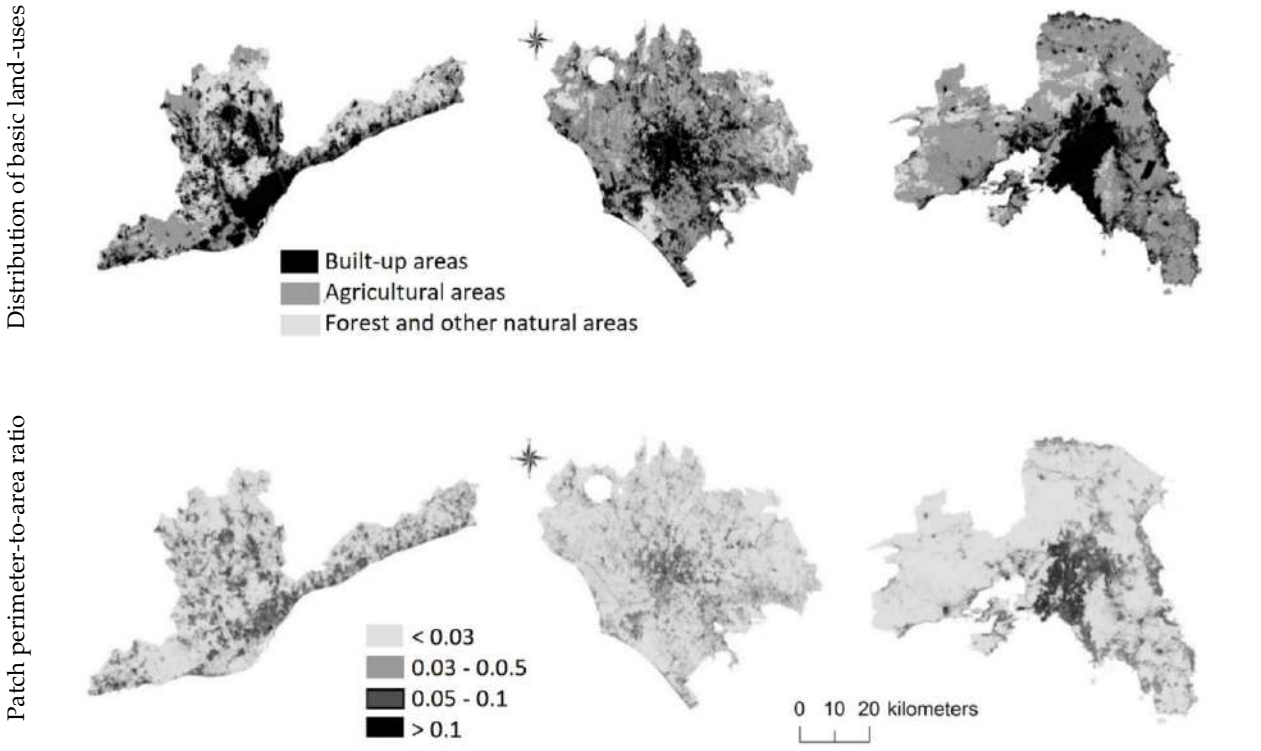


Figure 3.6. Land-use maps in Barcelona (left), Rome (middle) and Athens (right).

Maps indicate that the spatial distribution of Athens settlements is rather dense and compact; Rome settlements are more dispersed over the metropolitan area while Barcelona metropolitan structure shows an intermediate pattern of urban expansion. A morphological analysis of the three regions was carried out on the base of the level of soil sealing due to urbanization (Figure 3.7). Soil sealing is one of the major challenges that Europe faces today because it produces negative environmental impacts, reflecting the 'footprint' of each city (Salvati and Sabbi, 2011). A high-resolution map was used, covering the whole of Europe and produced by European Environment

Agency referring to the year 2006. The map consists of a raster data set of built-up and non-built-up areas including continuous degree of soil sealing based on multi-sensor and bi-temporal, ortho-rectified satellite imagery. The map represents the degree of sealing with a percent scale from 0 to 100, respectively from non-urbanized areas to hyper-compact cities, identifying an urban context with sealing values greater than 60%. Impervious surfaces were defined as pavement structures (roads, sidewalks, driveways and parking lots) covered by asphalt, concrete, brick, stone and rooftops. Table 3.5 reports the percent area of each soil sealing class. Results outline the compactness of Athens settlements, the discontinuity and heterogeneity of Rome settlements and the polarization in high- and low-density settlements observed in Barcelona.

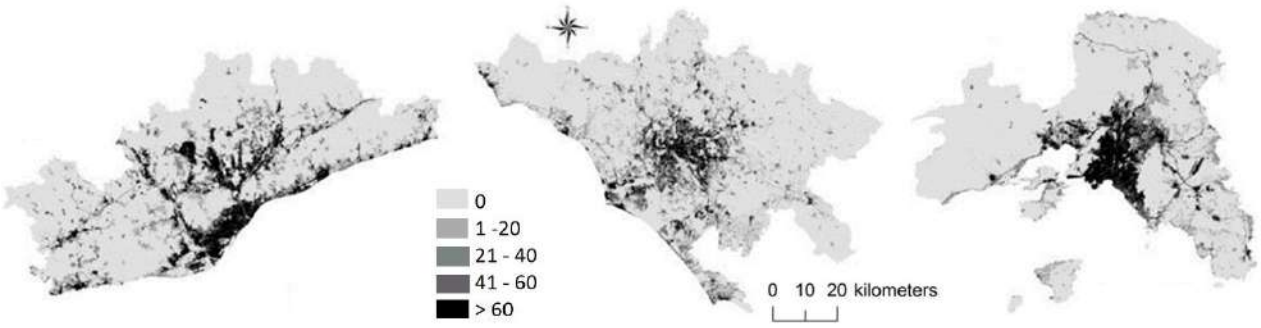


Figure 3.7. Soil sealing represtned in maps.

Table 3.5. Percent soil sealing by class in the three cities.

Class (%)	Barcelona	Rome	Athens
0	72.0	76.5	75.4
1 - 20	9.9	10.9	8.1
21 - 40	5.1	4.9	4.5
41 - 60	3.6	2.8	3.5
> 60	9.4	4.9	8.5

3.2.3. Population growth and urban expansion

The analysis of population growth may contribute to assess urban sprawl phenomena (Salvati and De Rosa, 2014). Three indicators were considered when assessing local-scale urban concentration or dispersion: population growth (i) in the short-term (2001-2011) and (ii) in the long-term (1981-2011) as well as (iii) population density. All indicators were derived from national censuses of population held by the representative National Statistical Office in Spain, Italy and Greece. These indicators allow focusing on the relocation of population in the outer fringe because of sprawl dynamics (Figure 3.8). Maps show that areas surrounding central cities are more attractive because of a growing population in respect to the neighbouring dense areas, contributing to consolidate urban sprawl.

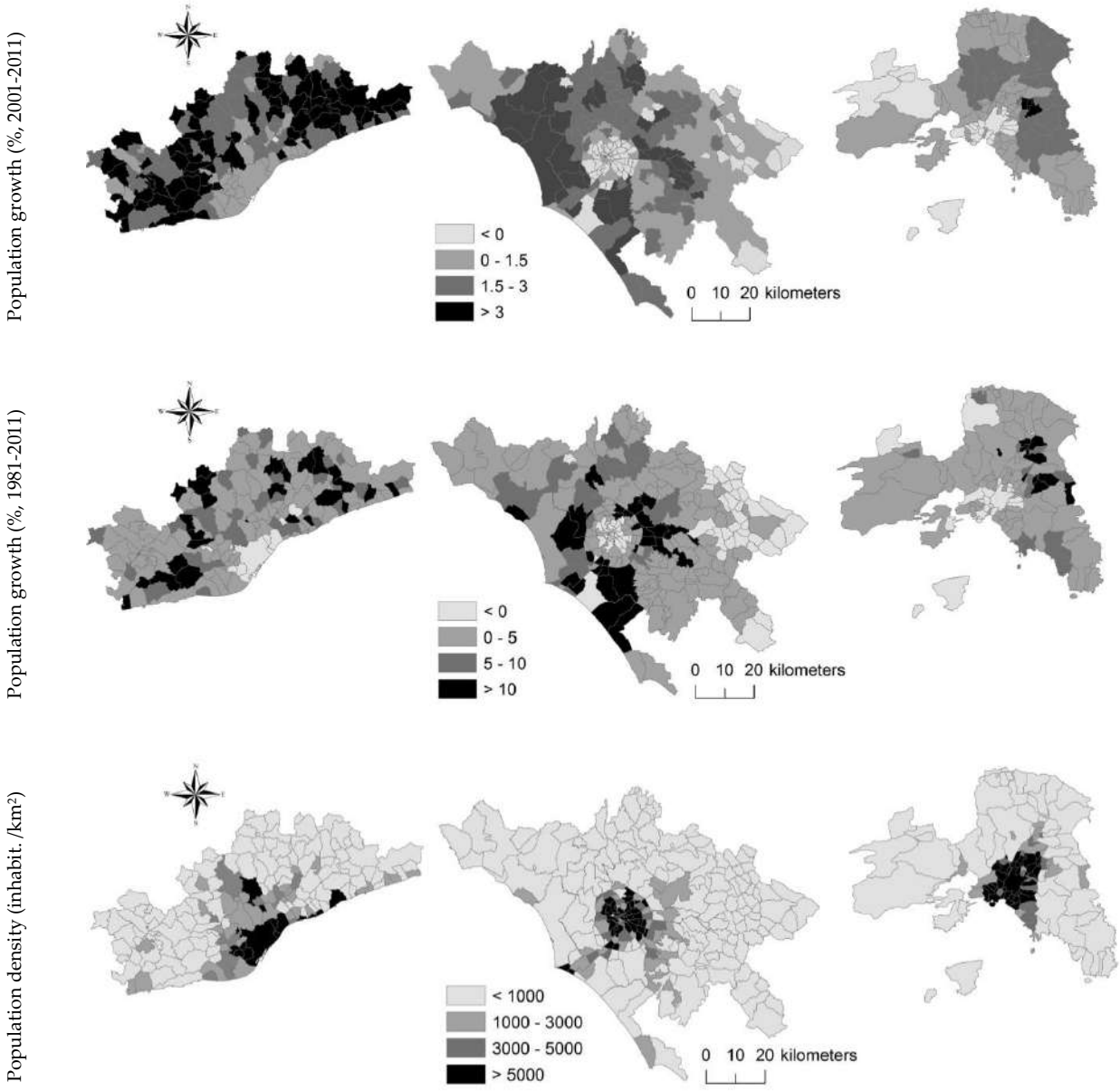


Figure 3.8. Recent population dynamics in the three cities.

Barcelona experienced diffused population growth in the last decade and a demographic stability with scattered expansion in the last three decades. Population growth in Rome was diffused along radial axes opposed to the inner city, reproducing a fragmented landscape at distances progressively further away from the central districts (Salvati et al., 2013a). In the last thirty years, municipalities with the largest increase in resident population were situated in the outer ring of Rome and particularly along coastal areas. The central city showed a moderate decrease in resident population, more pronounced in the last decade. Population growth in Athens was relatively stable over time, although with a moderate decrease in the central city over the last decade, possibly reflecting the opposition between shrinking industrial areas (such as Piraeus and surrounding districts) and sprawling eastern suburbs close to the International Airport. Population density discriminates Barcelona and Athens, more compact, from Rome, dominated by discontinuous settlements.

3.2.4. Urban morphology and infrastructures

City morphology is usually shaped by the interplay between biophysical, socio-demographic, economic, cultural and political contexts. A comparative analysis of urban design features, such as topography, infrastructural networks (e.g. roads, railways) and settlement patterns, contributes to understand how settlement morphology differs at the regional scale in Barcelona, Rome and Athens. For example, the elevation gradient is an important element shaping urban form and settlement expansion in the Mediterranean region. Rugged topography and sloping landscapes reduce the availability of buildable land, promoting more compact centers and urban growth mainly along the sea coasts or in the main lowland. The three cities were characterized by different elevation profiles as represented in Figure 3.9. Athens metropolitan region shows a rugged topography with more than 80% of the surface area classified as hilly or mountainous (> 200 m elevation). Rome expanded over the alluvial plain of the Tiber river with buildable land restricted by the Apennine mountain chain east of the central city. Barcelona is in an intermediate condition, with buildable land distributed along the sea coast and in some internal flat areas in correspondence with river valleys of regional importance.

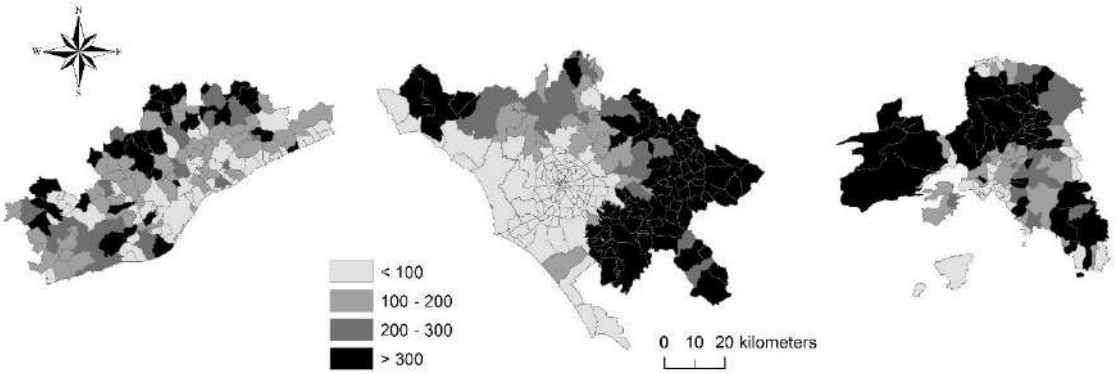


Figure 3.9. Classification of local municipalities in each study region based on mean elevation (m).

The spatial analysis of the main road network allows to identify central cities. With maps, the road network overlaps a population density layer (Figure 3.10). The analysis highlights three different metropolitan forms. In the case of Barcelona, the road network expands by connecting to other urban centers in the metropolitan area; in the case of Rome, the ring road concentrates the highest population density, which decreased gradually outside; finally, in the case of Athens, population density is low in the metropolitan area, growing in close proximity to Athens and Piraeus, where the roads are intertwined with each other.

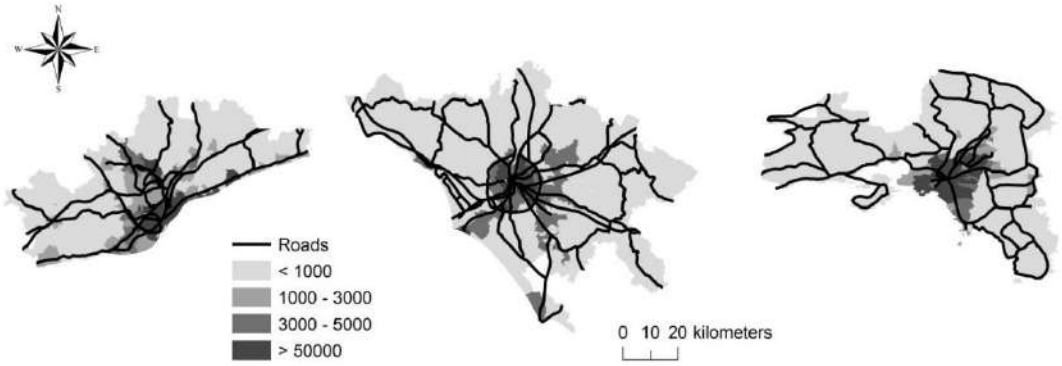


Figure 3.10. Main road network and population density (inhabitant/km^2) in the three cities.

Sprawl is associated to low density settlement composed of individual houses, in contrast to urban realities in which population density is high and buildings host several dwellings together. An indicator which compares the number of dwellings per buildings derived from the national censuses of buildings at the municipal level is proposed in Figure 3.11. A value approaching 1 means that for every building there is only one dwelling lives. This indicator is suitable to identify low-density settlements as a characteristic pattern of urban dispersion. Consolidated urban areas have high values of the indicator; the lowest values are observed in peri-urban areas in both Athens and Barcelona and around the central municipality of Rome, confirming the spatial heterogeneity typical of the Italian capital compared to the Spanish and the Greek cities.

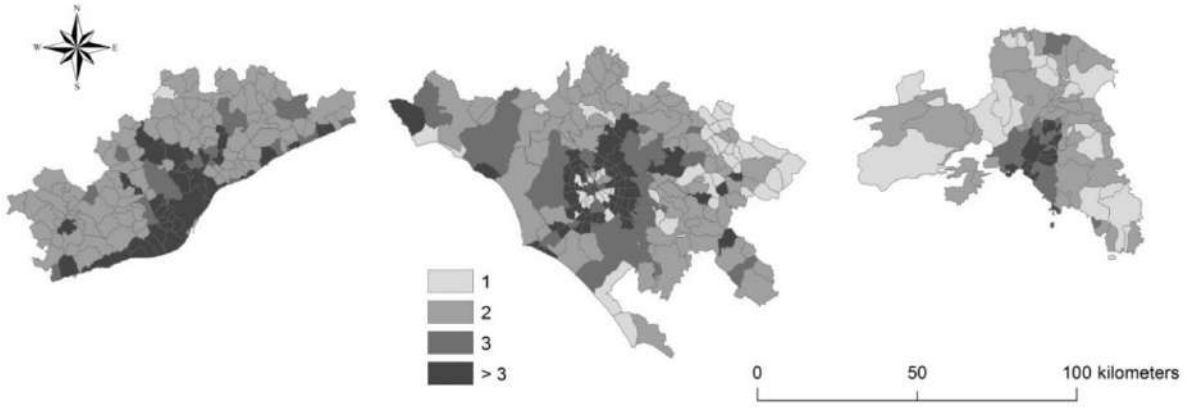
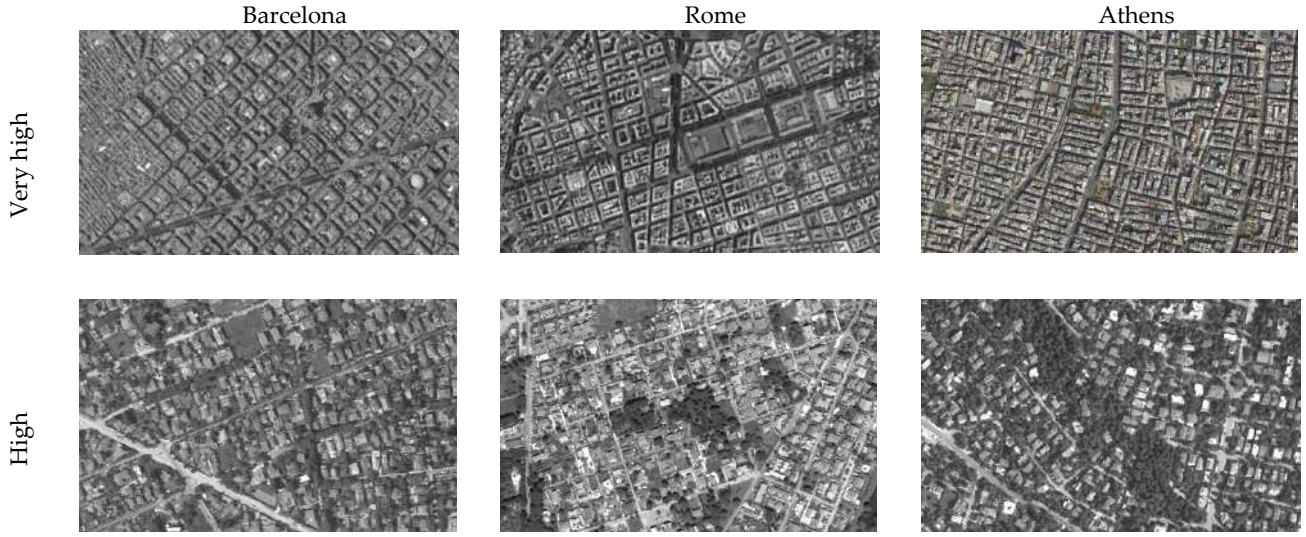


Figure 3.1. Number of dwellings per building in the three cities.

Aerial photographs finally allow to understand the main components of the urban landscape, identifying patterns of sprawl and summarizing the main results derived from the morphological indicators illustrated above. The following pictures (Figure 3.12) are intended as a comprehensive sample of urban fabrics, passing from hyper-compact settlements to the most typical contexts of sprawl, responding to the requirements of the socioeconomic indicators analyzed in the following sections.



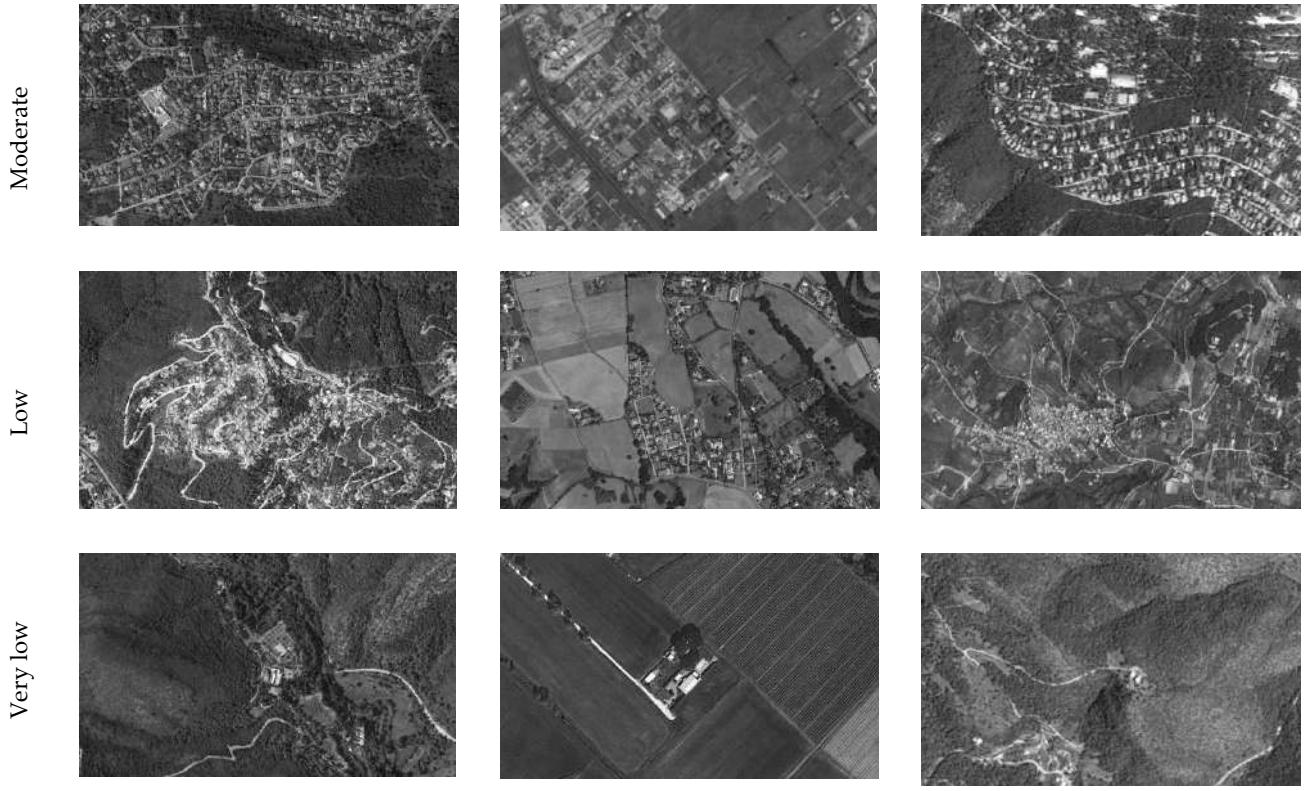
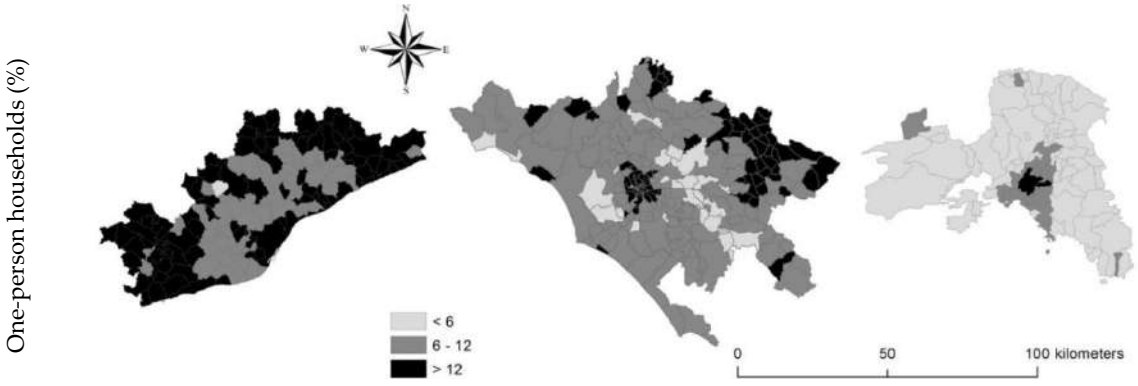


Figure 3.12. Settlement distribution patterns in the three cities by building density (from hypercompact to dispersed settlements).

3.2.5. The social context

Four indicators were calculated and mapped at the municipal scale with the aim to assess the dominant social context in the three cities (Figure 3.13): (i) percentage of households with one component in the total number of households; (ii) elderly index taken as a proxy for aging processes; (iii) percentage of foreigners (non-native people) in the total resident population; and (iv) percentage of graduates in the total resident population. These indicators were derived from the national censuses of population and allow for a comprehensive picture of the socio-spatial urban structure based on population structure, demographic dynamics and education level, considered as relevant factors of sprawl in the Mediterranean region (Torrens, 2008; Gargiulo Morelli and Salvati, 2010; Gibelli and Salzano, 2006).



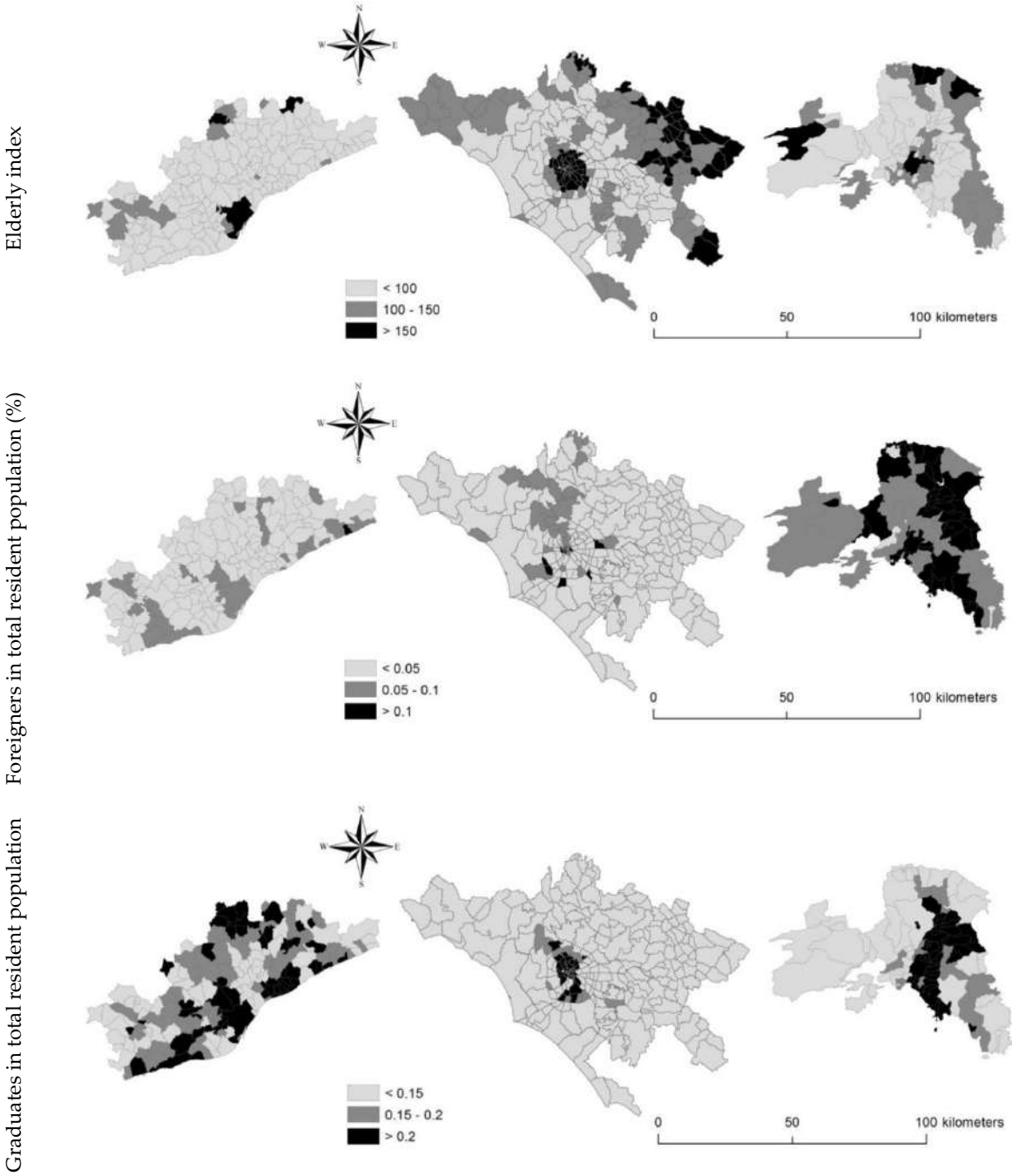


Figure 3.13. Social indicators in the three cities.

The average number of components per family is rather similar in the three cities. Barcelona shows values ranging from 1.7 to 2.8, with prevalence of medium-small households, with 2.4 average components at the metropolitan scale. Athens shows moderately higher values ranging between 2.3 and 4.0, with 3.2 components per family on average. Rome ranks in the middle with average household size amounting to 2.9. In all cities large households tend to settle in suburban areas. By contrast, one-component households settled prevalently in consolidated urban areas. According to López-i-Villanueva et al., (2013), household structure affects housing demand. One-component households (e.g. older people or adults who live alone) are concentrated in urban areas, due to their preference to have more accessibility to services, while large families, usually composed by a couple with two or more children, choose residential neighborhoods, surrounded by natural amenities and with low population density. Figure 3.14 confirms this spatial trend outlining that the

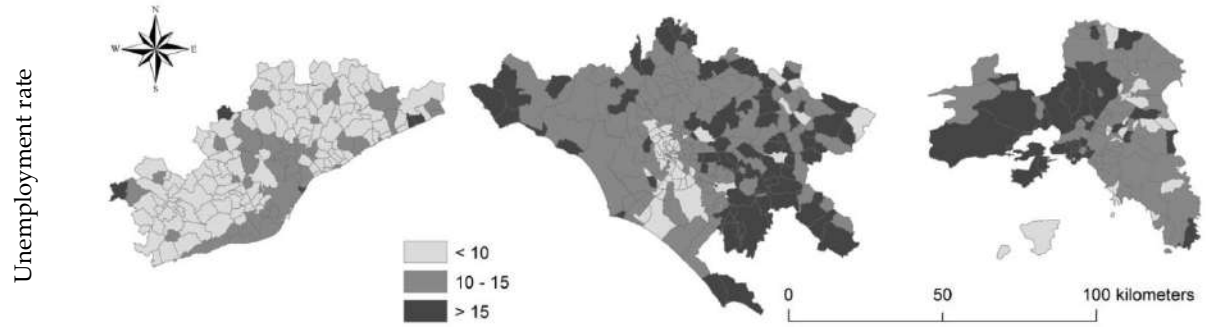
highest number of households composed of one person is concentrated in dense urban areas decreasing (more or less) rapidly in the metropolitan region of all cities investigated.

Elderly index completes the picture illustrating a distribution of elder population around the central city of Barcelona, while inland, rural municipalities showed high values of the index, together with some urban districts in Rome. In Athens, population aging was observed in the urban area and, more scattered, in some coastal and inland peri-urban municipalities. The spatial distribution of the elderly index reflects the dominant demographic pattern in the three cities possibly influencing the overall processes of urban sprawl. The proportion of foreign resident population was also discriminating among cities: Athens host the largest foreign population compared with Barcelona and Rome. By contrast, the spatial distribution of graduates (tertiary education) follows a typical urban gradient in all cities, being higher in the central city and decreasing in peri-urban areas. However, differences can be observed between Barcelona and Athens, with a more spatially-polarized distribution of graduates in Athens compared with Barcelona.

3.2.6. The economic structure

Economic indicators allow identifying the peculiar features and functions that characterize each metropolitan region. The productive structure of the three cities was investigated considering (i) unemployment rate; (ii) average of the declared income; (iii) share of entrepreneurs in the total resident population, and (iv) share of workers in credit, insurance and business services in the total workforce, as relevant indicators derived from the National Censuses of Population (Figure 3.15). The employment rate is the highest in Barcelona (58% on average); in Rome, several municipalities have a low or medium-low employment rate, while in Athens high employment rates can be observed especially in Eastern Attica. Unemployment rate is lower in Barcelona and much higher in Rome while in Attica an east-west boundary was observed with unemployed population concentrated in the western industrial districts.

Together with employment and unemployment rates, declared income is a key indicator when assessing the socioeconomic context influencing sprawl in Mediterranean cities. In Barcelona, the municipalities with the highest income (> 25,000 euros per-head) are situated close to the inner city or along the sea coast; the municipality of Barcelona has intermediate values of per-head income. In Rome, the highest incomes are concentrated around the consolidated city expanding along the coast. In Athens, the highest incomes were found in the eastern part of the region reflecting socioeconomic disparities between western and eastern districts.



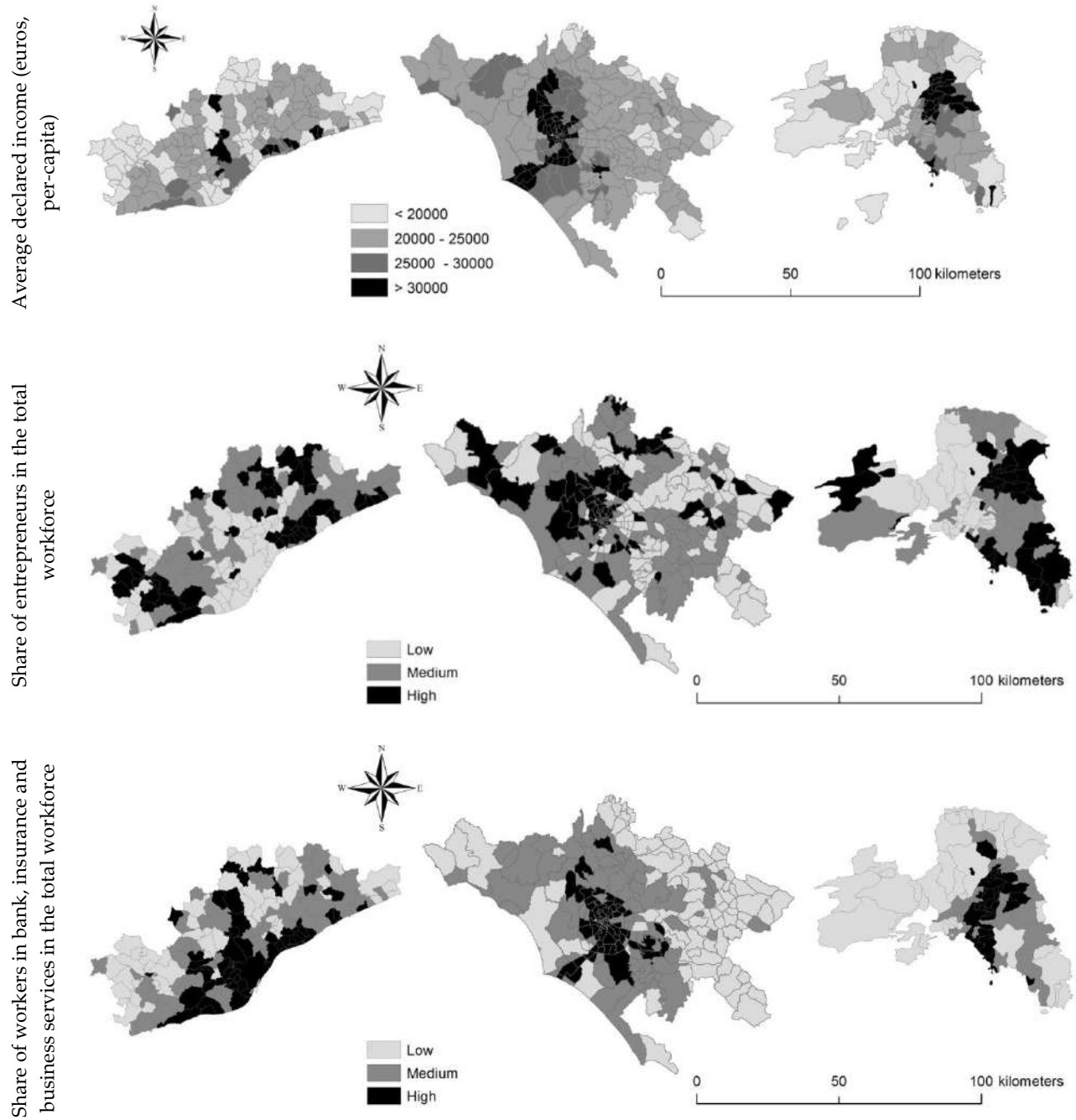


Figure 3.15. Economic indicators in the three cities.

Barcelona shows a relatively high density of entrepreneurs settled in the urban area and in some suburban municipalities. In Rome, entrepreneurs concentrated in suburban settlements especially along the sea coast. The maximum value of the indicator reaches 0.5 in Rome and declines to 0.2 and 0.3 respectively in Athens and Barcelona. Entrepreneurs concentrate in the eastern districts of Athens possibly indicating moderate class segregation. A similar distribution was observed for the percentage of workers in banking and insurance services in the total workforce. In the case for Barcelona, the highest values of the indicator were found in coastal municipalities with high tourism concentration, real-estate activities and second-home expansion. Workers in banking and insurance services were not concentrated in the inner city while being rather dispersed in the peri-urban region. In Athens, the eastern district attracts the highest percentage of workers in financial services in respect to the remaining metropolitan districts.

3.2.7. Narrating Mediterranean dispersed urbanization

Urban sprawl in Spain, and particularly in Catalonia, has shown multifaceted patterns and dynamics in the last decades. Spanish cities share some socioeconomic attributes such as the concentration of upper-functions and dense job markets, high rate of commuting, uneven expansion of the urban fabric and functional specialization of the different spaces within metropolitan areas. However, urban expansion is taking place in different ways in the Spanish regions due to cultural diversity and territorial heterogeneity (Serra et al., 2014). For example, the Barcelona metropolitan region is composed of the central city, partitioned into 10 urban districts, and 163 municipalities, each claiming a distinctive identity and with different social, political and economic contexts. In addition, the topography has played a major role in the evolution of the urban form, because of its homogeneity, being dominated by two mountain ranges (the Litoral range, with elevation above 700 m, and the pre-litoral range, with elevation above 1700 m) and two flat areas corresponding to the valleys of Llobregat and Besos rivers. The distribution of population in the metropolitan area of Barcelona is different from other European metropolitan regions. After two decades (1960-1980) of immigration from rural areas of southern Spain, Barcelona population has grown from 1.56 to 1.75 million, while in eleven towns around the central city, the population has grown more rapidly, from 0.57 to 1.41 million inhabitants. The resulting suburbanization combines high-density residential areas with industrial settlements, an irregular urban structure and population concentration in the inner city.

Since the 1950s, the metropolitan region has experienced an accelerated process of land consumption. Between 1950 and 1975, new neighborhoods were built-up at the border of traditional cities in order to accommodate the growing population from rural areas. Urban development shaped peripheries with crucial shortcomings of open spaces, services, infrastructures and public transportation. At the same time, the growing congestion in the inner city was boosted by the construction of second homes, often on cheap land of the outer fringes. Since 1975 a stabilization of population flows, and migration was witnessed even if the residential dispersion continued (Catalán et al., 2008). Between 1975 and 1986, coinciding with a period of economic recession in Spain, urban growth remained low. Land occupation somewhat receded, but residential decentralization was sustained through infilling processes of former urban 'islands. Many of the second homes built-up during the previous period became main residences consolidating dispersed settlements. In 1986 the economy began to get better causing a new period of land occupation in the metropolitan peripheries. The Olympic Games held in 1992 were a great opportunity for economic development of the area, promoting urban consolidation in the central city and a rapid expansion in the immediate surroundings. Some sub-centers also grew rapidly attracting population and economic activities especially at 20-30 km far from Barcelona city. The relationship between morphology and socioeconomic drivers confirms the preference contexts based on place-specific factors impacting the metropolitan districts in a different way and contributing to distinct phenomena of sprawl.

The landscape in Barcelona region is the result of historical processes adding successive layers that combine in different development patterns and urban schemes. The general trend has been an urban spillover directed to the outer part of the metropolitan region, with the most rapid growth at the margins - but not in simple concentric rings. Some authors have claimed that the Spanish sprawl is like the North American suburban model in terms of low-density housing typologies and new residential landscapes (e.g. Dura-Guimera, 2003). By contrast, findings are in agreement with other

studies (Catalán et al., 2008; Arapoglou and Sayas, 2009; Salvati et al., 2013b) stating that (i) in many Spanish cities sprawl is a relatively recent phenomenon; (ii) inner districts in Mediterranean cities have retained high population density; and (iii) due to the compact nature of southern European cities, morphology and intensity of sprawl are different from the American model - with a marked urban-rural divide.

Muñoz (2003) indicated that 40% and 70% of new houses respectively in the metropolitan area of Barcelona and in fringe towns were detached family houses. The relocation of industrial activities was another factor contributing to the expansion of scattered settlements in turn stimulating car ownership. Several industries have moved from the central area of Barcelona to the outer parts of the metropolitan region. Moreover, there was also an increase in retail sales' activities along fringe land. Large shopping centers often arose in areas that offer cheap land, with easy access to transport networks, and show the classic leapfrogging pattern of sprawl.

The actual urban form is shaped by the progressive saturation of the inner core that limits future growth of Barcelona municipality and its conurbation (Serra et al., 2013). Sub-centers have an important historical background and high population density, while neighboring municipalities offer affordable housing prices and modest densities showing the highest potential for growth. Soil occupation, loss in agricultural and forest land, decrease in settlement density and the high amount of bare land expecting for further development are important signals of landscape transformations and robust indicators of the new directions taken by urbanization. Land-use changes in the area testify an outward expansion of the consolidated city thanks to the high level of car ownership, the relocation of industrial and retailing activities to the fringe, the development of transport infrastructure and the conversion of second homes into primary residences.

Rome metropolitan area extends 5,355 km^2 encompassing the Functional Urban Area of Rome. The area around the city (the so-called 'Agro Romano') includes the alluvial plain of the Tiber river with fertile soils traditionally used for horticulture and tree crop. Rome region is administered by 122 municipalities, among which Rome municipality - partitioned into 19 urban districts - covers nearly 1285 km^2. Rome's municipality occupies a heterogeneous territory, with mixed impervious and semi-natural land contrasting the compactness of the historical center, where the most important functions are concentrated. With population movements, also urban design has changed. Two demographic phases have been identified in Rome along the recent growth path: a 'compact expansion' phase covering the time interval between World War II and the late 1970s, and a 'dispersed expansion' phase observed since the early 1980s. Population grew in urban areas at a higher rate than the suburban area (3.3% vs 1.8% per year) in the former time period. In the latter period population declined in the urban area (-0.2% per year) while rising in suburban areas at a relatively high rate, averaging 1.5% per year (Munafò et al., 2010).

During compact expansion, Rome socioeconomic structure was characterized by high unemployment rate, moderately low activity rate and an economic structure based on commerce, public services and constructions (Seronde Babonaux, 1983; Krumholz, 1992; Insolera, 1993). Since the 1980s, a moderate de-concentration of the inner city was observed. The growth of dispersed, medium-density settlements was rapid, while economic structure and social disparities were oriented along the urban gradient (Salvati et al., 2013a). In addition, during the last twenty years, investments were concentrated in the inner city depressing the development potential of suburban

areas (e.g. Gonzales, 2011). The formation of a highly fragmented suburban landscape around Rome did not significantly affect the social and economic characteristics of fringe districts which remained dependent on the core city (Allegretti and Cellamare, 2009). However, land consumption in Rome was found high during both 'compact growth' (due to population increase), and in the most recent time interval characterized by stable population. Salvati and Sabbi (2011) illustrated the consolidation of a scattered and chaotic urban fabric dominated by discontinuous and low-density settlements at higher distances from the inner city.

Rome's expansion is characterized by informal settlements, indicating how early sprawl processes have manifested in a deregulated urban context, partly lacking an effective spatial planning framework (Costa et al., 1991). After World War II, informal and spontaneous settlements alimented a rapidly-growing segment of the construction market. At the same time, a weak policy intervention faced with the shortage of public housing, leaving unresolved problems of urban poverty and social segregation for many years. In the 1960s, economic boom took place in Italy coinciding with a phase of 'building anarchy' in Rome, irrespective of the prescriptions stemming from the strategic Master Plan (1962). Urban plans remained unattended for a long time. In this way, early sprawl in the metropolitan area of Rome has been characterized by scattered settlement patterns.

Despite urban dispersion, Rome is a city with high levels of urban congestion, population concentration and economic polarization (Seronde Babonaux, 1983). Resident population decreased only recently in the core municipality (Salvati and Sabbi, 2011), as observed earlier in other Mediterranean cities (Durà-Guimera, 2003; Phelps et al., 2006; Couch et al., 2007; Chorianopoulos et al., 2010; Gargiulo Morelli and Salvati, 2010). Rome's morphology is the result of a scattered and perhaps chaotic development. Rome's Master Plan (1993-2008) identified tourism and culture as two main sectors promoting urban development. Measures for polycentric development were introduced promoting sub-centers (Gemmiti et al., 2012), strengthening some of the existing metropolitan poles, stimulating new economic activities and re-localizing urban functions (Allegretti and Cellamare, 2009), but this strategy was applied partially or revealed often ineffective (Salvati and Sabbi, 2011). In 2008, after more than forty years, Rome approved a new strategic Master Plan, incorporating rules and guidelines to orient the metropolitan development towards a more coherent urban design, devoting attention to the issues of decentralization and polycentric urban functions, provision of adequate services in suburban areas, environmental protection, cultural and historical heritage.

Attica is an historical region of Greece, which includes its own peninsula that juts into the Aegean Sea and where the Greek capital, Athens, is located. The region covers nearly 3,800 km^2 and is administered by more than 60 municipalities. The large urban areas of Athens are one of those European regions that still manifests a marked demographic increase (from 1.516.386 inhabitants in 1951 to 3.776.770 in 2011), followed by suburbanization processes which are transforming the typical rural landscape of Attica. The municipality of Athens host 650 thousand inhabitants in 2011 which added to the 3 million inhabitants of the metropolitan region. Athens development is a typical example of the informal growth path followed by several Mediterranean cities, which are transforming from compact to dispersed urban models. The interest in providing a detailed analysis of Athens development in the 20th century derives from various reasons. Athens is one of the few large urban areas of Europe still manifesting relatively intense demographic dynamics. The city also

represents an example for studying the impact of mega-events on urban development. The Olympic Games, besides placing Greece under the spotlights of the world's eyes, have made the city a case for discussing how new entrepreneurial modes are influencing urbanization.

Exhibiting similar traits with Spanish and Italian cities, Athens' economic structure in the post-war period was not exclusively based on manufacturing but on urbanization economies that triggered a slow process of industrialization (Leontidou, 1990). As a result, the city did not experience the usual deindustrialization/dis-urbanization wave noted in Northern Europe since the 1970s (Economou et al., 2007), growing in an un-designed fashion, with unplanned expansion based on self-financed property development, with limited public expenditure for urban infrastructure (Kourliouros, 1997). Urban development mainly occurred through illegal self-built housing, sprawling onto cheap suburban land with severe infrastructure deficiencies (lack of water and sewage systems, streets, public transport and social amenities). This led to social exclusion and vulnerability of the resident population, not to mention the deterioration of the landscape.

In the last decades, urban areas surrounding Athens and Piraeus (the main cities in Athens' conurbation) concentrated high population density; this indicates the urgent need to reorganize the metropolitan structure and its relationship with the surrounding areas of the country. The increasing demand for construction sites destined to residential, commercial, industrial and recreational uses, has led to an unpredictable expansion of the urban area beyond its traditional boundaries. The interested areas are those with the easiest access to the major cities of the region (where economic businesses are concentrated), the morphological features appropriate for construction businesses and the lowest land costs. The areas with the most evident features are Messoghia and Thriasio plain.

Compared with Barcelona and Rome, Athens displays a more compact structure in which the central city (including both Athens and Piraeus municipalities) maintains its role of economic attractor (Salvati and De Rosa, 2014), despite the presence of specific areas intended exclusively for low-density settlements (Kourliouros, 1997). The Athens metropolitan region was characterized by a marked urban-rural divide. However, throughout the 20th century, the traditional urban polarization in Attica have rapidly transformed, owing to exurban development, immigration and an ineffective planning system combined with a 'permissive' building code (Leontidou, 1990). These processes have modified the spatial distribution of economic activities (Kourliouros, 1997). The high population density reached in the inner city (nearly 20,000 inhabitants per km^2) has led to a reorganization of the metropolitan region. The increasing demand for construction sites destined to commercial, industrial, residential and recreational activities was leading to an inevitable expansion of the urban area beyond its traditional boundaries.

In the 1980s, workers and popular strata, together with rural immigrants, moved to the surroundings of Athens and Piraeus in search of affordable housing. Consequently, the density division between central cities and rural areas declined rapidly. The urban-rural depolarization has made possible thanks to the massive infrastructural development and the permissive urban policy. In the 1990s, middle- and upper-class exodus from inner cities became significant. The 2004 Olympic Games have played a crucial role in shaping sprawl at the regional scale. Urban competitiveness for natural and financial resources for the Olympic Games has grown more than ever, giving space to the entrepreneurial city model. In this context, mega-events are intended as a strong means of self-

promotion, stimulating infrastructural development and strategies for enhancing the image of the hosting city.

When Greece was awarded with the Games, urban and infrastructural projects were initiated (or completed) with the aim at reducing peripherality and improving the functional aspects and image of the metropolis (i.e. upgrade of the underground and suburban railway, expansion of the international airport and connection of the archaeological sites). However, the event has had two main consequences: the emergence of new spatial links between urban and rural areas and changes in real estate dynamics boosting sprawled urban expansion. Furthermore, these interventions have been distributed throughout Athens, determining a multi-nucleated urban regeneration program (Beriatos and Gospodini, 2004). Consequently, ribbon and leapfrog sprawl has been encouraged (Leontidou et al., 2007).

3.2.8. Re-setting the scene of 'Southern' sprawl?

Barcelona, Rome and Athens have maintained their typical configuration as Mediterranean European cities; however, in recent years, these compact cities sprawled in the surrounding area. It is from that moment that metropolitan areas outside urban boundaries, began to play a leading role in the urban design. The pervasiveness of sprawl is then demonstrable using multiple indicators which allow a comprehensive and comparative profiling of the three cities. Results showed how socioeconomic structures are divergent in Barcelona, Rome and Athens. Sprawl has occurred in each of the three contexts but has adapted in different ways, following the dominant economic and social forces. The combination of various contextual factors has promoted the development of new paths of dispersed urbanization (European Environment Agency, 2006). Contemporary cities expanding into metropolitan regions are destined to emerge with a competitive and innovative self-image (Longhi and Musolesi, 2007; Turok and Mykhnenko, 2007; Schneider and Woodcock, 2008; Fregolent and Tonin, 2013). For example, Barcelona and Athens were promoted as places of mega-events, such as the Olympic Games (Leontidou et al., 2007). In some ways, the Games acted as a "catalyst" for the reorientation of the space policy towards the improvement of the urban landscape. However, even in this case the two cities differ because, the urban context of Barcelona benefited greatly from the Games (Chen and Spaans, 2009) while the reverse applies to the Athens' case. More in general, cities have invested in their own territory in order to appear attractive and to improve place competitiveness (Chorianopoulos et al., 2010; Chorianopoulos et al., 2014). However, this trend was rather uncertain in the last decade due to the impact of recession (Kaika, 2012; Leontidou, 2014; Vradis, 2014). Moreover, especially in Rome and Athens, pre-crisis investments were dispersed throughout the metropolitan area (Richardson and Chang-Hee, 2004; Bruegmann, 2005; Phelps et al., 2006; Catalán et al., 2008), promoting suburban lifestyles - although with a leapfrog spatial pattern (Durà-Guimera, 2003; Muñoz, 2003; Salvati et al., 2013a).

Although Barcelona, Rome and Athens experienced different urbanization paths in the last decades, these cities have all seen the growth of dispersed settlements, driven by informal settlements and real-estate speculation. The results obtained suggest that sprawl outcomes are strongly associated to both economic and social issues at local scale and are influenced by territorial factors acting at wider scales. Territorial dynamics have indeed shaped the economic structure of the three cities: Barcelona polycentric structure reflects the consolidation of urban sub-centers scattered around the central city; the metropolitan area of Rome is more entropic and

morphologically 'scattered', outlining the low-density settlement growth up to the 1980s (Krumholz, 1992; Salvati and De Rosa, 2014); finally, Athens maintains its role as capital city consolidating a typical mono-centric form, despite the presence of specific areas destined to low-density settlements (Leontidou, 1990; Kourliouros, 1997; Couch et al., 2007). To summarize, sprawl phenomena in the study areas are mainly related to (i) changes in the use of land destined for low-density residential settlements, (ii) changes in urban lifestyles towards social homogenization; (iii) a moderate loss of economic attractiveness of inner cities partly counterbalanced with a gaining importance of sub-centers (e.g. Catalàn et al., 2008; Chorianopoulos et al., 2010; Munafò et al., 2010).

Settlement dispersion have led to economic polarization and social homogenization (Pacione, 2003; Leontidou, 1996; Beriatos and Gospodini, 2004). Socio-spatial disparities had also a negative impact on local cohesion and sense of belonging to the community, considered as one of the outcomes of sprawl (Gibelli and Salzano, 2006). In fact, the creation of settlements even more socially polarized may result from economic disparities linked to recessionary times (Vidal, Domènech and Saurí, 2011). Short-term dynamics have exerted a negative impact on local communities, increasing socio-spatial disparities and urban poverty, exalting the progressive degradation of city centers and enhancing conflicts of native residents with immigrants settled in deprived neighborhoods (Arapoglou and Sayas, 2009; Muñoz, 2003; Allegretti and Cellamare, 2009). In fact, the impact of the most recent economic crisis was particularly drastic in Athens (Kaika, 2012; Leontidou, 2014; Vradis, 2014) while being moderately less intense - although extensively recognized - in both Italy and Spain (e.g. Garcia, 2010; Chorianopoulos et al., 2014).

In order to successfully organize metropolitan areas in the future, investigation should be dedicated to regional/urban planning and sustainable land management. The aim is to guide towards a greater containment and management of sprawl. In recent years, local governments have proceeded to prepare strategic plans, which aim to administrate the entire metropolitan area and guide towards a truly polycentric development, which reduces the spatial divides, redistributing population and businesses throughout the metropolitan area, strengthening urban centers outside the city (as in the case of Barcelona and Rome) and avoiding social and economic unbalances.

Urbanization patterns are progressively shifting towards individual expansion paths, giving more value to place-specific factors than to regional-scale processes. The recent experience of Barcelona, Rome, Athens and the role of the local socioeconomic context shaping urban growth and socioeconomic disparities are an example of the diverging sprawl patterns observed in Mediterranean Europe. Sustainable management of urban (and non-urban) land is increasingly required to consider the diversity of processes of urban dispersion as an inherent element of urban complexity, based on the intimate and spatially-varying relationship between city morphology and functions. A comprehensive perspective on urban sprawl - incorporating economic, social, political and cultural issues - may shed more light in the recent transformations of Mediterranean cities, before and - possibly - after recession. Based on the findings obtained and the results of previous studies, further investigation focusing on the impact of economic crisis on short-term sprawl dynamics is required, privileging a comparative approach that covers different cases in the Mediterranean region.

3.3. Characterizing population dynamics and early processes of urbanization

Rural landscapes have evolved over centuries in Europe, leading local communities to act and shape land on the base of natural and social changes (Salvati et al., 2016a). This adapting process has guaranteed food, energy, new lifestyles and building materials, joining a cultural landscape that conserves a knowledge wealth in agronomic practices and construction techniques since the Middle Age (Kostrowicki, 1984). In past decades, especially the European Mediterranean areas, widespread land-use transformations and urbanization (also accompanied by e.g. industrialization, agricultural mechanization, land abandonment of rural areas) caused relevant environmental diseases and local soil erosion and degradation processes (Basso et al., 2000; Abu Hammad and Tumeizi, 2012; Salvati, 2014a). Agricultural landscape appeared affected to such transformations. Since the 1970s, Europe has undergone a rapid change of its rural landscape until then never seen, mainly due to socioeconomic factors (Meeus, 1993) and sprawl phenomenon (Salvati, 2014b). The latter invades rural areas away from the inner city (Bruegmann, 2005), giving rise to further changes, such as landscape fragmentation, homologation or spatial polarization, alteration of the traditional proximity pattern among uses of land, ecosystem deterioration and loss in biodiversity, in both quantitative and qualitative terms (Luck and Wu, 2002; Berling-Wolf and Wu, 2004; Song and Knaap, 2004; Seto and Fragkias, 2005; Couch et al., 2007; DiBari, 2007; Catalàn et al., 2008; Aguilera et al., 2011; Salvati et al., 2014b; Serra et al., 2014). The loss of landscape and environmental quality produced strong consequences in the agricultural sector where an intensive conversion of cropland to compact urban fabric happened, determining soil sealing and socioeconomic consequences due to marginalization of rural communities and damages of traditional agricultural practices (Munafò et al., 2010; Salvati, 2014b).

Cited article

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During the millenary human-landscape interactions (Alphan, 2003), urbanization adapts itself in rural areas, in terms of shape and structure, depending on the local-cultural customs that are usually linked to agricultural activities. Also, in Italy, sprawl has occurred as witnessed various studies (EEA, 2006; Couch et al., 2007; Salvati and Carlucci, 2016): its unique landscape has changed over time, conciliating its urban and rural contexts. The conversion of natural and agricultural land to urban uses and the expansion of compact settlements have caused high levels of soil sealing, habitat fragmentation and degraded landscapes (e.g. pastures, abandoned fields and low-intensity agricultural areas) that are located outside the towns (Salvati and Sabbi, 2011). Several inequalities are present in the Italian country, including population density, rural-urban forms, income and natural resource distribution, that lead also to thoughtful environmental problems (Salvati and Carlucci, 2011; Salvati et al., 2014a).

As in other Mediterranean contexts, sprawl was supported by the inclinations of systems towards illegal housing and land speculation (Weber et al., 2005; Polyzos et al., 2008; Ioannidis et al., 2009; Salvati et al., 2013a; Salvati, 2014b). Abusiveness and the lack of respect of the planning tools (determining by their limited and often weak efficiency) allow the rise of informal settlements, resulting into a land appropriation and uncontrolled process of building settlements since 1980s (Leontidou, 1990; Barata Salgueiro, 2001; Gargiulo Morelli and Salvati, 2010). Now dispersion process is slightly reducing, however, its effects are still visible in the territory (e.g. Catalàn et al.,

2008; Chorianopoulos et al., 2010; Munafò et al., 2010). Fortunately, there are few areas where the communities' mentality and their strong local agricultural identity have appeased the strong pressure of urban sprawl. In these contexts, sprawl took place in a milder way, avoiding serious environmental, natural and landscaping damages.

The work aims to analyze the urbanization processes, especially related with the phenomenon of sprawl in Tuscia, located in the heart of Italy. Central Italy can be considered a region where urban and rural areas coexist in traditional landscapes circumscribed by hills and mountains. Economic structure is structured by low- and medium-income agriculture and tertiary activities (such as commerce and the public sector) (Salvati, 2014a). Tuscia is still a treasure trove of great natural and agricultural value, regardless of whether the dispersive dynamics have also occurred there (Di Felice et al., 2014). It is expected that the main limit to the dispersive phenomenon is derived from the social and economic components, which have allowed to preserve its rural and environmental identity, protecting a portion of the Mediterranean landscape.

Although the literature has studied agriculture in its various aspects in the province of Viterbo (see e.g. Colantoni et al., 2016), there are few studies that deepen the relationship between urban and rural areas through economic, social and territorial prospective. The need to reflect on the sustainability and to face new environmental and natural challenges are necessary also in realities like Tuscia. The awareness and the sustainable behavior from citizens and economic activities, the implementation of appropriate policies and actions, the conservation and management of the typical landscape are just some topics that allow to think about the future of this reality with high landscape-natural value in order to ensure the most relevant opportunities.

3.3.1. Dynamics and processes of urbanization in rural Tuscia

Tuscia coincides with the province of Viterbo (NUTS3 region), located in the north of Lazio region, in the heart of Italy (Di Felice et al., 2014). It includes 60 municipalities that surround the capital city of Viterbo that is located enough centrally. This area has a total surface of 3615.24 km², with a population density equivalent to 87 hab./km².

The structure of GVA (understood as gross domestic product at market prices per inhabitant, from Istat database in 2011) in the Latium region occupies the 7th position (29726.7), preceded by other key regions such as Lombardy, Trentino Alto Adige and Emilia Romagna (respectively 33597.6, 32032.1 and 33765.3), while the lower one concerns the nearby Campania (16458.6). At the provincial level, employment rate of Viterbo (equal to 54.4, reported by the Istat census in 2011) is close to the other Latium provinces (e.g., Rieti with 54.6 and Rome with 61.1), observing an average value compared to the national context (the lowest score was recorded in Naples (36.2) and the highest in the province of Bolzano (69.5), followed by other provinces like Bologna and Milan (respectively 69.5 and 66.3) which are the Italian economic driving forces.

The agro-forestry system is the element that contradistinguishes its landscape, always strongly linked with ancient traditions, such as the pasture, grain-crops, vineyards, olive groves and forest management. Tuscia is characterized by the presence of typical traditional activities related to the production of food crafts (including cheeses, olive oil, hazelnuts and wine) and handmade decorative objects (such as wood carving, hand-work clay). The agricultural sector is still well ingrained in the Tuscia. Following the Istat data (2011), the ratio of people employed in agricultural sector in total people employment, evidences that the Latium region records only a value of 2%,

while other Italian ones assume higher values (e.g. Emilia-Romagna: 3%; Campania: 4%). However, large cities have low rural occupation rates, such as the province of Milan (0.2%), of Rome (0.7%), of Naples (1.3%) and of Bologna (1.7%). While in the case of Latium region, Viterbo's province reaches 6.4%. Much of the surface area of Viterbo's province consists of cultivated lands, forests and pastures (approximately 94%, with soil sealing values equal to 0, therefore a significantly rural and natural vocation), distributed along the urban-to-rural gradient. In fact, the conjugation of rural and natural contexts increases the quality of the environmental system. Forests cover a total surface of about 360,000 ha, covering the 19% of the entire province. The water heritage has numerous rivers, torrents and lakes (such as Lake Bolsena), of volcanic origin. For orographic characteristics, climatic conditions and for its land use, Tuscia represents a typical area of central Italy (Colantoni et al., 2016).

3.3.2. History of early processes of urbanization

Dispersive processes took place also in Tuscia, escaping from the control of urban planning but following the only rules dictated by the agricultural mentality. The province of Viterbo is certainly more livable compared to the neighborhoods around the capital city of Rome. According Salvati (2014b), Rome's metropolitan area can be considered a semi-compact and dense Mediterranean city experiencing sprawl and then structural and composition changes of its peri-urban landscape. Its main landscape transformations comprise: (i) mixed developments of settlement densification and dispersion through an increasingly degraded and fragmented agricultural landscape, (ii) reduction of the semi-natural land into scattered woodlands, especially in marginal areas and (iii) increasing mixing of the traditional rural landscape and anthropic settlements (Salvati, 2014b). In the Viterbo's province, the low-density settlements are situated in a less chaotic and scattered way if it is compared to the Roman experience. Many buildings constructed possess a regular planning permission for rural building. Until recently, this title could be obtained simply: the possession of minimum rural lots and being agricultural entrepreneurs were essential regardless of income derived from the relative activities. In this way, a legalization of soil consumption was permitted in such rural contexts. However, the rural countryside and the forest system have managed over the years to remain as they represent a current income for many families. In fact, today, the highest densities (with degree of soil sealing > 60) assume a very low percentage compared to the whole territory (only 0.47%), located in Viterbo and few urban centers. The entire area is characterized by the absence of sealing (approximately 94% of the provincial surface is natural and rural), with settlements with medium-low density. Despite having experienced informal practices, the administrations of the Viterbo region have always kept an approach detached from the industrial sector, defending the agricultural activities and the local workforce. These policies made possible to better protect the local countryside, avoiding a possible further urbanization and pollution.

The investigation was performed by statistical analysis and GIS processing. The unit of analysis is based on the municipal areas. The latter constitute the province of Viterbo, which represents the NUTS 3 region in the European classification. Municipalities seem to be the most relevant spatial unit for analysing land-use transformation, useful also for environmental reporting of land vulnerability to desertification and informing sustainable management of rural and peri-urban land (Salvati and Zitti, 2009).

A total of 49 indicators has been developed from a collection of variables regarding each municipality present in Tuscia (Table 3.6). Most of them were obtained from the Italian National

Census of Population and Buildings available on the web site of the National Statistical Office (Istat), mainly referring to the last census carried out in 2011. Indicators allow to investigate on the area though an exhaustive socio-economic and demographic description, providing an extensive classification of territorial structure at the local scale. In addition to these variables, a work carried out by ISPRA (Institute for Environmental Protection and Research) was considered (Munafò et al., 2015a), in which a set of indicators have been developed to analyze how and where soil consumption affects the Italian context, from the regional scale to the local one. ISPRA also provides a National map of soil consumption at high resolution (2012), attaching a table of relative indicators elaborated.

Table 3.6. List of the context variables elaborated.

Abbreviation	Extension Name	Unit	Source
DEM51-11	Demographic Variation 51-11	%	Istat - Census
DEM51-81	Demographic Variation 51-81	%	
DEM81-11	Demographic Variation 81-11	%	
DEM01-11	Demographic Variation 01-11	%	
DEM11-15	Demographic Variation 11-15	%	
DEN	Density	inhabitants / km^2	
BUID50	Buildings Constructed until 1950 / Total Buildings	%	
BUID80	Buildings Constructed until 1980 / Total Buildings	%	
BUIREC	Buildings recently constructed from 1981 / Total Buildings	%	
MSH	Medium Size Household	population/families	
UNIFAM	Family from a Component / Population	%	
EAGR	Employed in Agriculture / Total Employed	%	
ECRED	Employed in Credit and Insurance and Business Services / Total Employed	%	
EMPL	Employment Rate	%	
AGE	Aging Index	*	
MAGE	Medium Age Index	*	
COMM	Commuters / Population	%	
LMOB	Long Mobility	*	
AINC	Average Income Per Capita	€ / population	
DIST-VT	Distance from Viterbo	km	Istat - Census GIS
DIST-ROME	Distance from Rome	km	processing
SC	Soil Consumption	ha	Elaboration on
NAT	Mainly Natural Areas with A Very Low Density / Surface Area	%	Ispra - sinanet. isprambiente web
LDA	Urbanized Areas with Low Density / Surface Area	%	site
HDA	Mainly Artificial Areas with High Density of Urbanization / Surface Area	%	
ART	Artificial Surface / Surface Area	ha	Ispra - Elaboration
RAA	Anthropized Area / Surface Area	%	on CLC 2012
CROP	Crops / Surface Area	%	
WOOD	Forests / Surface Area	%	
WATE	Water System / Surface Area	%	
ICROP	Intensive Crops / Surface Area	%	
CRS	Residential Areas in Continuous Fabric / Surface Area	%	
DRS	Residential Areas Discontinuous tissue / Surface Area	%	
CHA1-1	Conversion from 1 a 1 from 2000 / surface area	%	Ispra - Elaboration
CHA2-1	Conversion from 2 a 1 from 2000 / surface area	%	on change CLC
CHA2-2	Conversion from 2 a 2 from 2000 / surface area	%	
CHA2-3	Conversion from 2 a 3 from 2000 / surface area	%	
CHA2-5	Conversion from 2 a 5 from 2000 / surface area	%	

CHA3-1	Conversion from 3 a 1 from 2000 / surface area	%	
CHA3-2	Conversion from 3 a 2 from 2000 / surface area	%	
CHA3-3	Conversion from 3 a 3 from 2000 / surface area	%	
RSS0	Soil Sealing0 / Surface Area	ha	EEA - Elaboration
RSS1-20	Soil Sealing1-2 0/ Surface Area	ha	on soil sealing map
RSS21-40	Soil Sealing21-40 / Surface Area	ha	
RSS41-60	Soil Sealing41-60 / Surface Area	ha	
RSS61-100	Soil Sealing61-100 / Surface Area	ha	
TEXP	Total Expenses / Surface Area	€ / kmq	Elaboration on
MEXP	Mobility Expenses / Surface Area	€ / kmq	Interior Ministry's
LEXP	Land and Environment Management Expenses / Surface Area	€ / kmq	database
YPRG	Year of the most recent municipal planning instrument	year	Latium Region's report

The Italian Corine Land Cover (CLC), always provided by ISPRA to 2012, is useful to analyze the land use and to understand how the Viterbo's province is structured. CLC was classified into the following classes: residential areas in continuous fabric; residential areas in discontinuous fabric; anthropized area (excluding residential areas); crops land; intensive crops area; forests; water system (with sea, lakes and rivers). Following the data elaborated by Ispra, also the land use change cartography was considered (considering the recent available years: 2000, 2006 and 2012). The indicators elaborated estimate how many hectares of each type of land-use have been converted to another use since 2000, with the aim to assess land-use transformation in Tuscia and which tissue has mostly suffered from this changing. Territorial transformation identifies the conversion from the original state of land-use to the final use, classifying from 1 to 5, respectively: the urban areas; agriculture territories; forest areas; wetlands; and water system.

Another mapping, that has been chosen to validate the reliability of the CLC, is one available from the EEA web site, in relation to the degree of soil sealing. It is a raster data set of built-up and non-built-up areas, including continuous degree of soil sealing, in percentage terms from 0 to 100, in aggregated spatial resolution (100 x 100 m). The relationship between sprawl and soil sealing is very strong: in recent years, the debate around the evaluation of soil sealing through effective monitoring schemes is very actual (European Environment Agency 2006). And Italy represents an emblematic area where there is an increasing rate of conversion of land to urban uses (Munafò et al., 2010). It was chosen to identify five classes of soil sealing: the one corresponding to '0', for the natural contexts natural; classes '1-20' and '21-40' for contexts with low density; class '41-60' identifying settlements with medium density; and then the class that indicates the most dense and compact situations (represented by the class '61-100'). Ispra also provides a national map of soil consumption at high resolution (2012), attaching the relative table of indicators elaborated.

The data regarding the Certificates Advisory were also collected from Interior Ministry at the level local. The database is an open data accessible by everyone from the website of the Interior Ministry, in order to ensure transparency from the institutional activities, such as those of municipalities. In this way, annual final balance sheet (2012) can be analyzed in terms of total charges, focusing on expenses of mobility, territorial and environmental management.

Territorial objectives and strategies, defined by each Italian region, constitute a programmatic reference to the provincial and municipal policies and their respective programs and sector plans. The Master Plan (PRG) is the predominant spatial instrument at the municipal level. The Latium

region regularly checks the general situation regarding the local urban planning. Through such report, another analysis variable refers to the year in which the last approval (or update) of the PRG was done, observing if a condition of inertia of spatial planning tools exists.

All these data have been developed into useful indicators with the purpose to evaluate the study area. Very often the indicators express the standardization of the selected variables compared to its municipal area surface, identifying where the most interesting contexts are located. A simple correlation verified whether there is a relationship between two indicators, demonstrating their inclination to change together. Among the statistical calculations, a non-hierarchical cluster analysis (using standard k-means computation strategy) was carried out to classify municipalities into homogeneous spatial clusters using a Euclidean distance, with a hierarchical cluster with similarity index (Euclidean) with algorithm "paired with group". The processing of maps regarding the indicators and their spatial analysis using GIS program allowed the detection of the most interested contexts and the validation of the results obtained (Salvati et al., 2011).

3.3.3. Emerging results

Demographic changes help to track the settlement processes in Tuscia. Figure 3.16a shows how, from the 50-80s, the largest population change was located around the main town of Viterbo; as time went on, the city of Viterbo has recorded a lower demographic change, which in turn has assumed maximum levels into the surrounding contexts and especially along the coast of Tarquinia and Montalto di Castro (Figure 3.16b). It is exactly in this period that even the phenomenon of second homes manifested, where the evolution construction occurred also along the Tyrrhenian coast. This trend is a typical character of sprawl present throughout the Mediterranean area. In recent years (Figure 3.16c), demographic change was heavily concentrated around Viterbo, its surrounding municipalities and coastal municipalities.

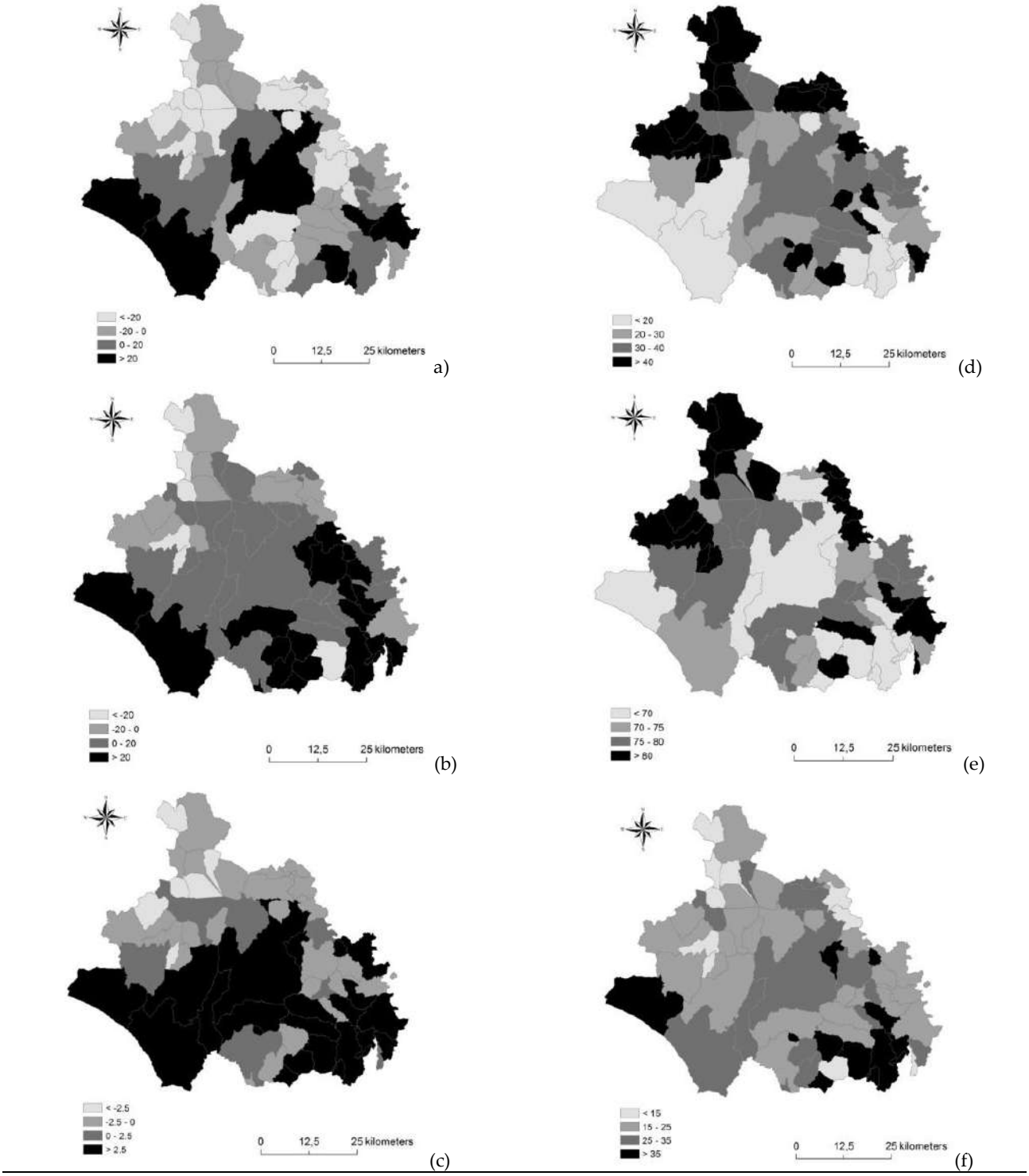
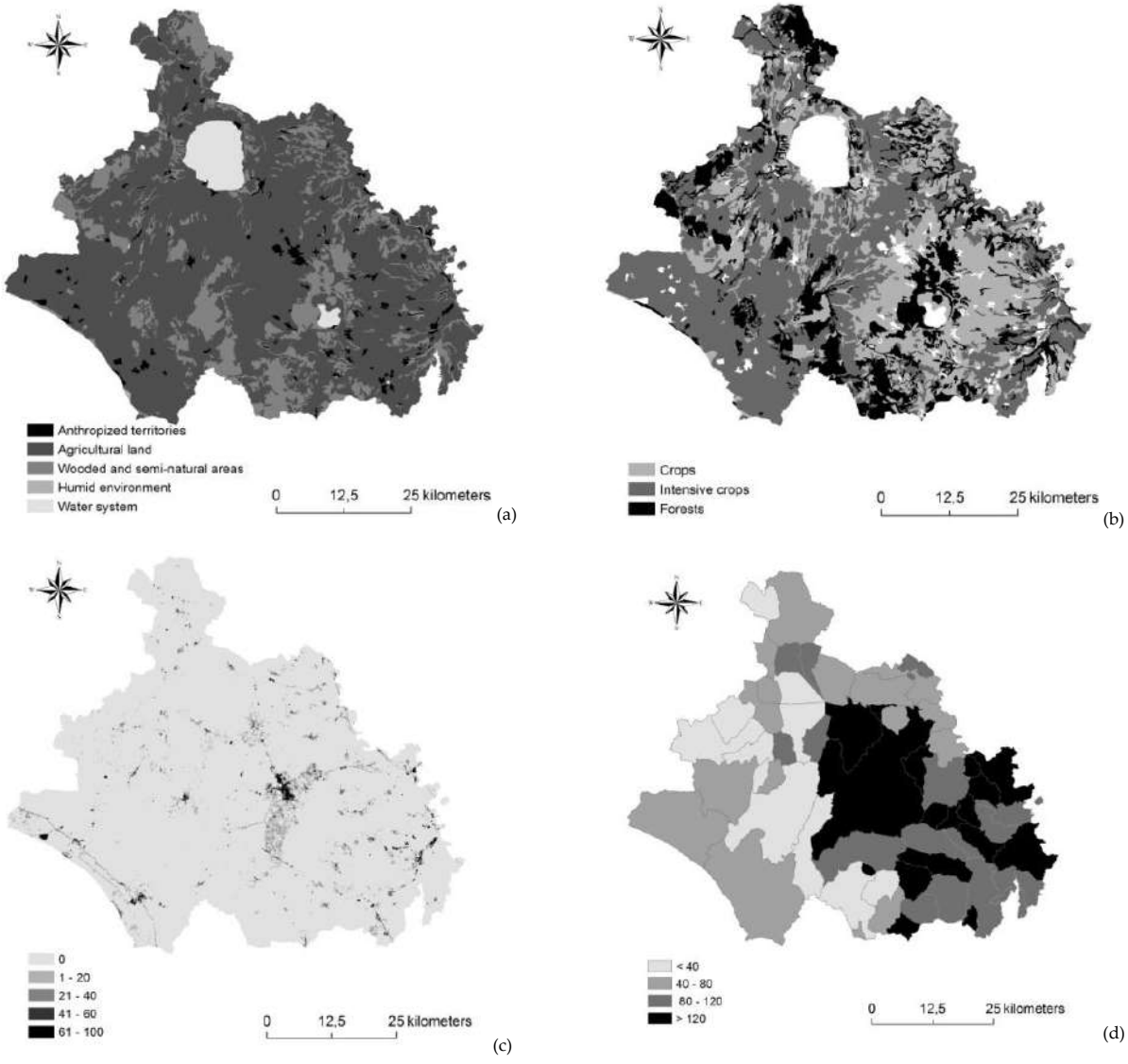


Figure 3.16. Population change from 1951 to 2015 and built-up evolution. Maps correspond to: DEM51-11 (a); DEM51-81 (b); DEM11-15 (c); BUID50 (d); BUID80 (e); BUIREC (f). Figure 3.16 (d, e, f) shows the built-up evolution. Until the 50s, the largest number of buildings were around the Viterbese hinterland. From 1950 until 1980, a building boom occurred in the area surrounding the city, highlighting that also sprawl manifested itself in the Tuscia countryside. The latest map instead concerns the percentage of buildings built in the last thirty years, where the dynamic dispersive has always taken place mainly in the coastal area and around the chief town.

Despite demographic and settlement change, Tuscia strongly maintained its rural connotation. Figure 3.17 reflects on its territorial structure. In 2012, maps reveal a predominantly rural land use. This is demonstrated by CLC's map (Figure 3.17a), classified following the level 1, that highlights where the anthropized and agricultural territory, forestry, humid environments and water system are placed. Figure 3.17b shows only the agricultural fabric, which extends across the province of Viterbo, leaving a few empty spaces (that indicate other land-uses). Rural activities are primarily concerned with crops, while more intensive crops are located near the sea, where the largest greenhouse cultivation is settled. Soil sealing (Figure 3.17c) confirms the CLC's data, pointing out that the largest concentration of populated areas (with soil sealing degree > of 60) and density (Figure 3.17d) are close to the crop lands (Figure 3.17f), while the most intensive farming spatially corresponds to the very sparse built settlements. Soil consumption summarizes the most affected contexts by illegal building and urban sprawl (Figure 3.17e). The affected municipalities are located around Viterbo and along the coast. The latter assume a mostly artificial configuration with medium-high density of urbanization and soil sealing compared to the total municipal area. Through a comparison, maps relating to demographic change are like those for population density and soil consumption.



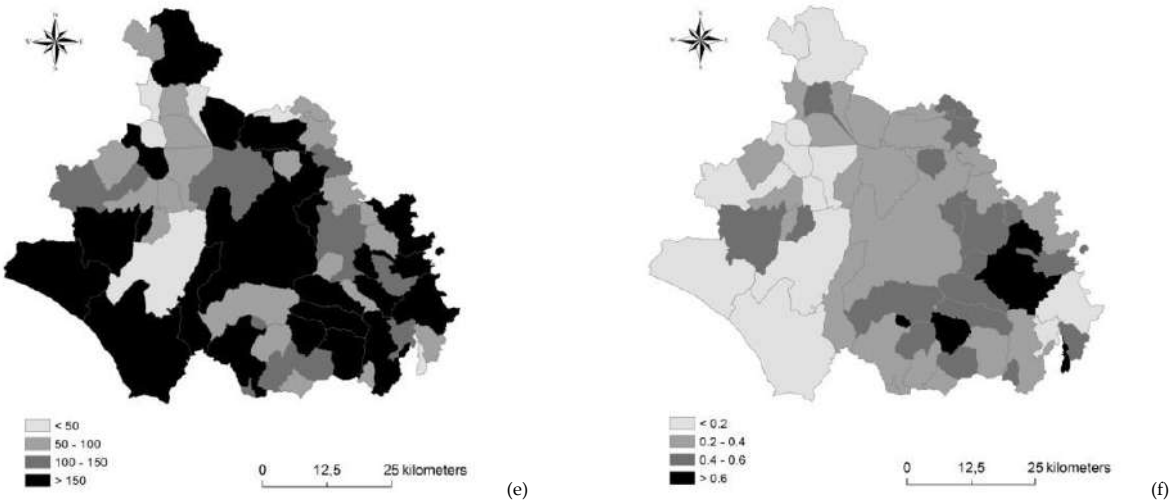


Figure 3.17. Elaboration of the territorial configuration of Tuscia: CLC's classification (2012) according to the level 1 (a); classification of the rural context of CLC (2012) according to the type of cultivation (b); soil sealing map (c); density (d); soil consumption (e); percentage of agricultural land (excluding intensive crops) on the surface area (f).

Results demonstrated that the social - economic determinants have driven the dispersion process in Tuscia (much more than planning tools), affecting also the environmental component. Correlation permitted to understand the relationship between the various indicators developed. Table 3.7 contains only an extract of the correlation regarding the indicators of density (DEN), aging index (AGE), percentage of residential areas discontinuous tissue on the total municipal surface area (DRS) and the conversion from rural areas to urban fabric since 2000 on the total municipal surface area (CHA2-1). Density (DEN) is positively correlated with the: percentage of newly buildings (since 1981) on the total built-up elements; family medium size; degree of commuting; percentage of total expenses, expenses relating to the viability and management of the territory and the environment in respect of the municipal area, in 2011; percentage of urbanized areas with low density compared to the municipal area; anthropic contexts, in particular regarding residential areas discontinuous tissue with degree of soil sealing with values ranging from 1 to 60, where there is a strong presence of rural activities. In recent years, a re-compaction processes have been assisted where the cultivation area has a considerable presence at the local scale. Instead density is negatively correlated with: percentage of buildings constructed until 1980 on the total of buildings; single-family households compared to the resident population; employed in the agricultural sector on the total employed; old age and middle age index; predominantly natural areas or with very low density ('0' degree of soil sealing) compared to the municipal surface. Correlation demonstrated that sprawl has taken place in the Viterbo's context, but avoiding those high natural settings, where the strong presence of the primary sector has prevented an excessive land consumption. These contexts are identified by a greater value of aging index, where construction activity dates to the 80s. Aging index is also associated with very low values of demographic change, average income per capita, employment rate, while there was a strong presence of single-family households (consisting of elderly widowers) and employees in the agricultural sector.

Table 3.7. Extract of the correlation with the three most interesting indicators (population density 'DEN', aging index 'AGE', discontinuous residential areas on total municipal area 'DRS', land-use conversion from rural areas to urban areas from 2000 on total municipal area 'CHA2-1') in columns and processed variables in rows with value > |0.5|.

Variables	DEN	AGE	DRS	CHA2-1	Variables	DEN	AGE	DRS	CHA2-1
DEM51-11	0.6	-0.7	0.6	0.6	NAT	-0.7	0.5	-0.7	
DEM51-81					LDA	0.7	-0.5	0.7	
DEM81-11	0.6				HDA				
DEM01-11	0.6	-0.7	0.7	0.5	ART	0.8	-0.5	0.8	0.8
DEM11-15	0.6	-0.7	0.6	0.5	SS0	-0.8		-0.7	-0.6
DIST-VT					RSS1-20	0.7		0.7	0.5
DIST-ROME	-0.6	0.7			RSS21-40	0.8		0.7	0.7
DEN	1.0	-0.6	0.8		RSS41-60	0.7	-0.5	0.7	
BUID50		0.7			RSS61-100				
BUID80	-0.6	0.6	-0.7		RAA	0.5			0.9
BUIREC	0.6	-0.6	0.7		CROP	0.5			
MSH	0.6	-0.7	0.6		WOOD				
UNIFAM	-0.6	0.6			WATE				
EAGR	-0.5	0.7			ICROP				
ECRED		-0.5			CRS				
EMPL		-0.5			DRS	0.8	-0.5	1.0	
AGE	-0.6	1.0	-0.5		CHA1-1	0.5			1.0
MAGE	-0.6	1.0	-0.6		CHA2-1				1.0
COMM	0.5	-0.9	0.5		CHA2-2				
LMOB					CHA2-3				
AINC		-0.6			CHA2-5				
TEXP	0.9	-0.5	0.8		CHA3-1				
MEXP	0.6		0.5		CHA3-2				
LEXP	0.9	-0.5	0.8		CHA3-3				
SC					YPRG				

Typical contexts of sprawl with medium-low density are concentrated in the southern part of Tuscia and along the coast. Indicator 'DRS', that refers to "Residential Areas Discontinuous Tissue / Surface Area", is positively correlated with demographic change (especially the recent ones), density, percentage of recent buildings since 1981 and commuters, medium size household, all the voices of the municipal expenses (stating that a greater dispersion also implies a greater collective cost), intermediate levels of soil sealing (between 1 and 60). DRS appears opposite to natural contexts, with soil sealing with values equal to 0, where a discordant trend of percentage of buildings constructed until 1980 and old age indicators is reported.

As expected, correlation has revealed a modest change of agricultural land intended for urban use since 2000, compared to the other changes in land use. The conversion from agricultural land to urban fabric involved most of the municipalities, highlighting however that the case study was not exempt to land consumption processes. Capranica, Montalto di Castro, Monterosi, Orte, Proceno and Viterbo are the municipalities that have seen a re-functionalization of the built-up environment. The transformation of agricultural land for new buildings occurred mainly where there was a strong demographic change and medium-high population density, with soil sealing values greater than 0, as a result to prevent natural territories. This outcome demonstrated that the Viterbese area avoids converting highly natural contexts into a scattered and fragmented spatial organization.

Results affirmed that the greatest demographic change occurred in dispersed contexts, with degrees of soil sealing between 1-60. However, it is strongly linked to the "density" factor, which not allow to lose too much building fabric in the surrounding countryside. Now large group of young population live in these contexts, moving around the territory. They have a medium - high income levels, preferring the convenience of living close to more dense and compact contexts. As correlation highlighted, Tuscia represents one of the few Italian cases in which most of the soil consumption is recorded in urban contexts, with medium - high density, minimizing extensive land consumption (Munafò et al., 2015).

A non-hierarchical cluster analysis (using standard k-means computation strategy) was carried out to classify municipalities into homogeneous spatial clusters using a Euclidean distance. The k-means cluster analysis identified three clusters characterizing the main territorial typologies present (Figure 3.18). With dark colours (value 1 in the legend), Viterbo, Ronciglione, and San Lorenzo Nuovo emerged as some of the most compact and dense settlements. Dispersive areas, with medium density, surrounded by the countryside (value 2 in the legend), such as Vetralla and Caprarola, appeared occupying the southern part of Tuscia. Highly natural areas are represented with the lightest colours (value 3 in the legend), indicating contexts with high landscape value, characterized by occasional low-density settlements: Acquapendente, Bagnoregio and Barbarano Romano are some municipalities that are included in this last cluster.

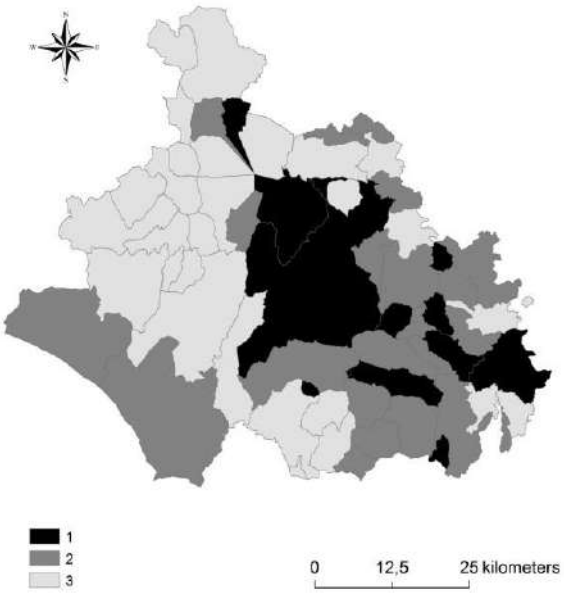


Figure 3.18. Results from the k-means cluster analysis.

Validating the preliminary results, a hierarchical cluster with similarity index (Euclidean) was carried out with algorithm "paired with group" (Figure 3.19). In this case four specific clusters are identified, however confirming the results obtained from the k-means cluster analysis. The group with the city of Viterbo is the one that stands out compared to other clusters, given its features. It identifies the most compact contexts, where high values are related to the positive demographic change especially in recent years, employment rate and income per capita. Its society is mainly composed by young people, enough large families and commuters. Urban settlements have experienced a decline until the 80s, then have a significant increase in recent years. In fact, this cluster recorded the highest provincial values of soil sealing, rural land converted into urban surface and

soil consumption. Surrounded by the typical Viterbo's rural landscape characterized by extensive crops (as olive and hazelnut), these municipalities do not assume a strong rural quality, like other contexts of Tuscia. This condition results into an increase in expenses, which weighs in municipal budgets especially for the items concerning the territorial and environmental management (see also Burchell et al., 2005). A specific group (cluster 2) stands out in the hierarchical clusters with similarity index. Blera, Vejano, Canino, Ischia di Castro and Arlena di Castro appear different from other municipalities. Despite it is like the cluster 4 (according to the k-means cluster analysis, the two clusters are included in the same group), these municipalities are differentiated by the high naturalness and extremely low population density, where sprawl has not been successful there. With a constantly negative demographic change, its residents are mostly older and low-income people, static in the territory, resulting into a low employment rate despite a mighty agricultural presence. Such socio-economic structure has preserved a rural area, where the land consumption rates are the lowest around the case study. In fact, the built-up evolution has stopped in the 80s, in favour of agriculture (mainly in the intensive form, generally concentrated in the western area). The certain socio-economic and landscaped profile affects also the municipal budgets, in which the costs are the lowest. The third cluster concerns particularly the southern part of Tuscia. Medium-high values of land consumption identify an area where urban sprawl has occurred, without excess, and the real estate expansion has grown over time, especially along the coast where tourism has developed in the last decades. The advent of urban dispersion may be the consequence of a collective application, resulting in an effective economic and social welfare as, in this cluster, are recorded: a consistently positive demographic change, which has improved especially in recent years; strong territorial mobility; medium - high employment rates, young people and large families, confirming the presence of an active population. Results describe a cluster characterized by medium-density settlements, surrounded by a rural landscape, ranging from intensive farming in the west to less intensive crops in the east. Finally, the fourth cluster identifies the most natural environments, with medium-low density. The area did not report high land consumption rates and a consequent urbanization process. In fact, soil consumption and rural areas converted for urban purposes have been very limited. Its territorial connotation, especially in the western municipalities, is delineated by a landscape where intensive agriculture is its protagonist. This assumption derives a reflection concerning the environmental issues. The cluster can be recognized as those economically disadvantaged and marginal contexts (with negative demographic rates, lower incomes and employment rates), in which attend situations of social - economic inequalities and environmental and eco-systemic problems (Salvati et al., 2014a).

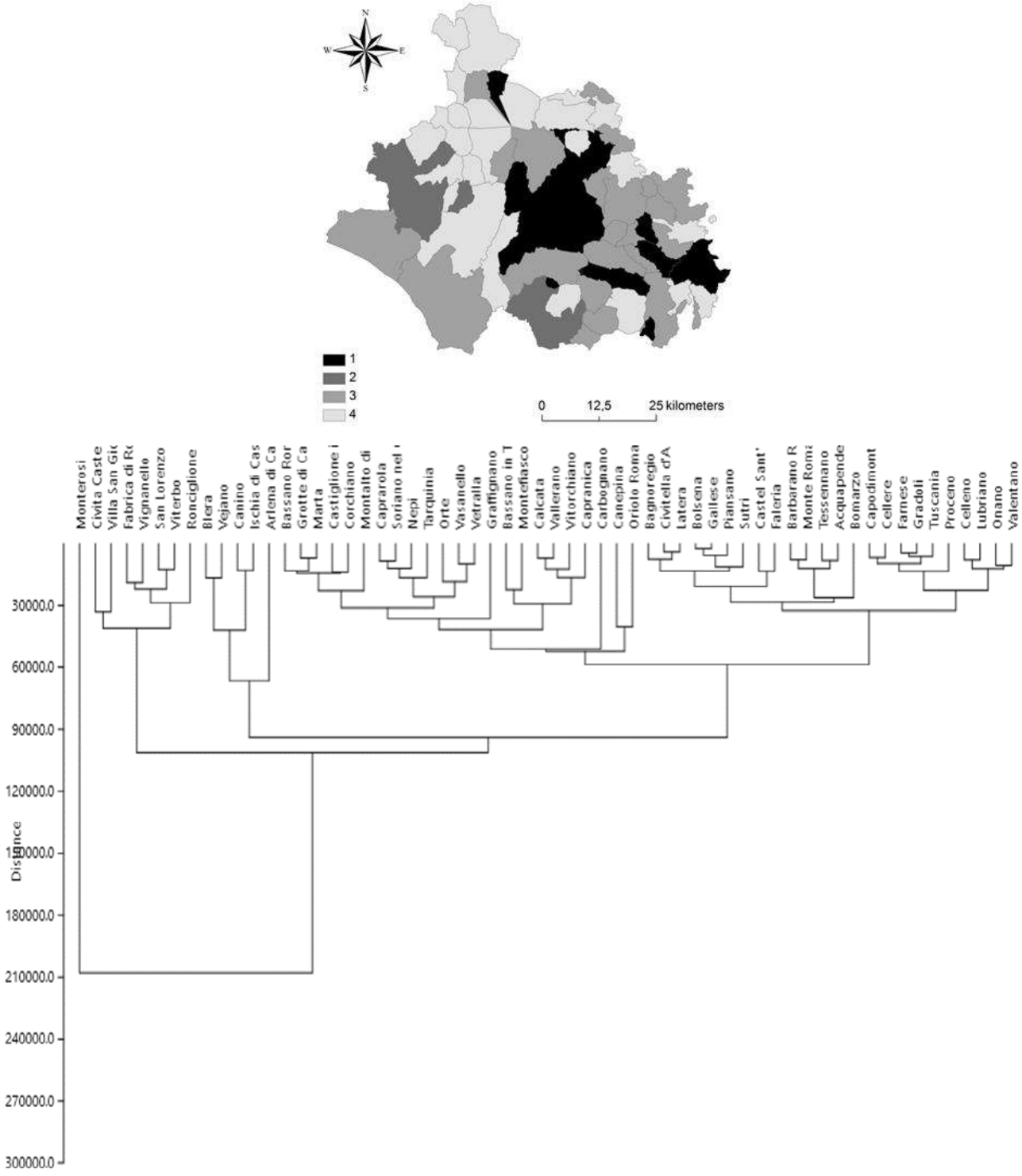


Figure 3.19. Results from hierarchical clustering.

The existence of four clusters also confirmed a different political implication regarding the land management instruments. Results detected a general status of inertia of the Master Plan (PRG) in the whole province of Viterbo. The municipalities with the highest density rate and land consumption (specifically the cluster that includes the city of Viterbo) possess a more dated PRG. Only the municipalities of Soriano nel Cimino, Proceno and Acquapendente (which belong to other clusters) have performed an adjustment (known as "variante") of such instruments recently (from 2010 to present). This passive attitude leads to a territorial design that can be defined defective,

because Master Plan is not updated regularly, due also to a not-effective spatial policy. During the analysis, a negative correlation (-0.5) demonstrates a noticeable relation between the year of the most recent land use planning tool (or PRG) and the indicators HAD and SC. In fact, the municipalities with a more dated local planning instrument have recorded a greater soil consumption and a higher high-density urbanization rate.

3.3.4. The importance of agriculture in urbanization processes

The Mediterranean basin represents an example of the durable interaction between natural ecosystems and human activities (Alphan, 2003; Ferrara et al., 2014). Since the 70s, urbanization, land abandonment, crop intensification, soil degradation, new economic dynamics and other many factors have determined land-use changes in southern Europe (Paul and Tonts, 2005; Catalàn, et al., 2008; Nolè et al., 2009; Chorianopoulos et al., 2010; Munafò et al., 2010; Ferrara et al., 2014). Drivers, such as and changes towards urban sprawl (Cakir et al., 2008) and intensive agriculture (Alphan, 2003), have altered the traditional landscape, fragmenting it and endangering the most vulnerable rural and peri-urban areas (Salvati et al., 2016a). The collective costs that result from the dispersive phenomenon has already been studied (Burchell et al., 2005). Municipal budgets have investigated on this problem, highlighting that the higher expenses are localized in the medium-high density contexts with a greater presence of dispersive residential areas. Results produced a series of reflections that range to social - economic issues (e.g. situation of segregation and polarization, economic marginality,) and environmental and natural (e.g. phenomena of land degradation) that affected disadvantaged rural regions of southern Europe (Iosifides and Politidis, 2005; Wilson and Juntti, 2005; Salvati and Carlucci, 2011; Salvati et al., 2014a). Likewise, Tuscia appears affected by these factors but in a very circumscribed way. In terms of land use change, dispersive dispersion has been severely restricted and limited in the already dense contexts. Urbanization processes seem to be also influenced by the strong local identity. In this way, natural and agricultural landscape has remained mostly unchanged in time. In fact, Viterbo is one of the few Italian cities that have recorded a low percentage of land consumption referred to the whole municipal area (Munafò et al., 2015). The presence of a very consolidated rural setting allowed to limit an excessive soil consumption over time, maintaining its traditional socio-economic profile.

Crop intensity and soil compaction characterize the Viterbo area, despite also being sensitive to the of urban sprawl, soil sealing and environmental phenomena (e.g. salinization and fire risk) (Salvati et al., 2011). The preservation of rural-cultural landscapes in peri-urban contexts can result complex due to the interactions of various elements (i.e. biophysical, social, economic, cultural and institutional). Peri-urban areas should be treated as rural landscapes, which can be effectively protected in ecologically long-term feasible approach, thanks to a reasonable human pressure and tools that integrate "social" functions (derived from the primary sector) with eco-conscious local communities (Salvati et al., 2016b). This has happened in the Tuscia: land consumption has limited the denser areas, leaving the agriculture to be the unique protagonist of the landscape, without scattered settlements.

Agriculture has managed to limit the spread and informal dispersion processes in the Viterbese area. Results revealed that municipalities with more recent Master Plan have suffered less land consumption. A constant control of urban planning instruments would allow, for example: to avoid potential damaging impacts to the environment and to the built-up system; to ensure continuous

territorial maintenance and conservation; and to verify compliance with the guidelines dictated by higher institutional levels. Outcomes have then encouraged reflections on the regulatory framework. With its Regional Development Plan General (PTRG), the Latium region imposes a set of specific objectives that must be followed at lower territorial levels, such as: to enhance the vocations and restrict land consumption; to limit urban sprawl; and to safeguard agro-forest landscapes. General and specific objectives imposed by the region must be included and adapted to each local context (through the municipal Master Plan). However, given the regional variability, different realities exist such as Rome with its complex metropolitan area and the province of Viterbo with a strong rural vocation. Agriculture correspond to a real added value for the Viterbese territory. The final purpose of rebalancing urban, peri-urban and rural areas into a new urban-to-rural 'sustainable continuum' is essential (Salvati et al., 2016b). Agricultural activities, which should improve their organization particularly in the peri-urban contexts, could help to achieve a better ecological equilibrium in the neighbouring urban systems, enhancing their sustainability degree (Silvestri and Bonari, 2010). For example, the development of circular economy in agriculture can limit and control farming wastes, utilizing them as a sustainable strategy (Jun and Xiang, 2011). Agricultural waste can be used as biomass (such as biochar), giving energy to productive processes (and maybe even residential) (Pan et al., 2015; Zabaniotou et al., 2015). A sustainable cycle of economy is the way to reach a real development between environment and economy (Frayssignes, 2011; Jun and Xiang, 2011). The awareness that the local resources can result an effective opportunity for the future is decisive. The establishment of agro-energy districts can be a standpoint of sustainable development, as possible solution for: create a network of actors and stakeholders; reuse waste and natural resources and other clean energy; increase rural identity, quality and protection of landscapes; ensure the sustenance of local businesses (e.g. Frayssignes, 2011; Shamsuzzoha et al., 2012; Tziolas et al., 2016). Associated with an assessment which identifies other environmental issues and land vulnerability degree to the various factors of instability on a spatial scale compatible with the development of planning (Salvati et al., 2016c), even Tuscia, as other national contexts, should implement sustainable land management strategies, continuing to protect its agricultural landscapes.

3.4. Understanding latent patterns of urban expansion in large metropolitan regions

Earlier studies on size, growth, and distribution of cities have identified economic factors (such as scale and agglomeration) as major determinants of urban growth at local scale (Allen et al., 2004; Barras, 2009; Barr and Cohen, 2014). However, traditional analysis of urban growth revealed sometimes inadequate to identify and explain recent developmental paths in contemporary cities, since regions have taken on new - and more complex - spatial assets and processes of change (Cheng and Masser, 2003; Couch et al., 2007; Brenner and Schmid, 2014). In these regards, non-economic (demographic, social, cultural, political and institutional) forces have played a key role in the recent expansion of metropolitan systems (Gargiulo Morelli et al., 2014). Processes of urban expansion were characterized by a continuous interplay between vertical growth (promoting concentration of population and economic activity in central locations and determining a consequent increase in floor-to-area ratios) and horizontal expansion, with addition of new settlements - often with a modest vertical profile - to more peripheral urban locations (Cuberes, 2011). Coherently, Hamilton et al., (2004) identified a two-dimensional typology of governance in metropolitan regions, being strongly influenced by vertical or horizontal types of urban expansion.

Cited article

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The interplay among path-dependent factors of vertical and horizontal growth should be more extensively evaluated. Identifying the role of social forces and territorial conditions in both forms of urban growth is a particularly demanding task since urban expansion depends on multiple agents operating at different spatio-temporal scales (Allen et al., 2004; Arapoglou and Sayas, 2009; Carlucci et al., 2017).

Quantitative approaches grounded on existing data and indicators have revealed spatial heterogeneity in both intensity and direction of urban expansion (Brown and Liu, 2001; Cheng and Masser, 2003; Barras, 2005). In these regards, sequential city growth has been widely studied using cross-country and/or regional population data, although theory can be adapted to other relevant indicators and socioeconomic processes (Cuberes, 2011; Sánchez-Vidal et al., 2014; González-Val and Lanaspa, 2016). Individual trajectories of growth with divergent demographic rates, economic performances, settlement characteristics and land-use made analysis of urban expansion even more difficult (e.g. Coiacetto, 2006; Barras, 2009; Ferrara et al., 2014).

The emerging complexity in national, regional and local urbanization patterns requires an improved comprehension of the main factors that influence building activity resulting in metropolitan growth (Brown and Liu, 2001; Barras, 2005; Chorianopoulos et al., 2010). It was demonstrated how building cycles affect urban morphology and functions, being intimately associated with political, institutional, cultural and planning factors (Allen et al., 2004; Buzar et al., 2007; Glaeser et al., 2008). While indicators of building activity from official statistics have been adopted in the analysis of spatial trends in construction industry and housing markets, their use in the discrimination of different types of urban expansion was relatively scarce (Morris and Jonathan, 2005; Jiang et al., 2007; Polyzos and Minetos, 2013).

Indicators of building activity allow a wide-ranging assessment of the different dimensions of urban growth at various observation scales (e.g. building characteristics, settlement morphology, urban hierarchy, metropolitan functions) and their consequences for spatial organization of changing socioeconomic contexts (Lin, 2002; Salvati et al., 2013a; Kourtit et al., 2014). Based on these premises, a novel index (VHG) was proposed discriminating long-term vertical from horizontal urban expansion. The VHG index was easily derived from official statistical sources such as the national census of buildings, building permits' surveys and/or building registers. These statistics are characterized by high cross-country comparability, regularity in data updating, standardization in survey techniques, and spatial detail. Based on this index, changes in vertical and horizontal profile of settlements at nregional and local scale were analyzed in Greece, a country experiencing particularly complex urban cycles in the last century (Salvati, 2016), and, more specifically, in the metropolitan region of Athens (Colantoni et al., 2016), at 12-time intervals covering one century between the 1910s and the 2010s. Building dynamics were analyzed empirically, hypothesizing that sequential urban cycles may impact housing characteristics, the spatial distribution of settlements and socioeconomic structures in a different way (Zitti et al., 2015; Rontos et al., 2016; Salvati and Serra, 2016). An exploratory analysis of contextual socioeconomic indicators was finally run to provide an enhanced overview of long-term patterns and processes of urban expansion in districts displaying distinct cultural, demographic, economic and social characteristics. Multivariate exploratory analysis was adopted here with the aim to identify local socioeconomic contexts (based on 16 variables, section 2.3) associated with specific values of the VHG index evidencing horizontal or vertical growth. In this way, it was possible to define a latent, multivariate relationship between the local socioeconomic context and the dominant pattern of urban expansion in each Greek municipality.

3.4.1. Horizontal vs vertical growth

The study area includes the whole territory of Greece (301,330 km^2). By referring to the most recent local administrative system (the 'Kallikratis' regime), 326 municipalities ('dimoi') were adopted as the elementary analysis' unit for this study. Greek municipalities are homogeneous areas from the administrative and socioeconomic standpoint and reflect relevant geographical gradients based on elevation, distance from the sea coast and from the main urban centers (Salvati et al., 2016a). Greek landscapes are rather heterogeneous and fragmented, with relatively compact settlements surrounded by rural areas mixing a diversified agricultural matrix with forest patches, pastures and wetlands (Di Feliciantonio and Salvati, 2015; Salvati et al., 2016a; Cecchini et al., 2018). For a long time, the Greek urban system has been centered on two rapidly-growing metropolitan areas (Athens and Salonika), with medium-size cities (Iraklio, Volos, Kalamata, Patra, Larissa, Chania, Ioannina, Kavala, Kozani) expanding (more or less) slowly (Delladetsima, 2006). De-concentration of inner cities was observed in more recent decades (Giannakourou, 2005), leading to a progressive expansion of residential settlements in fringe districts (Colantoni et al., 2015). Since the 1990s, peri-urban areas have attracted massive immigration flows, reinforcing metropolitan growth with population relocation at the fringe of large cities (Zambon et al., 2017a). With the 2004 Olympic Games, real estate speculation led to an increase of discontinuous settlements and dispersed residential units (Gkartzios, 2013), fueled by rapid expansion of road networks, especially in Attica (Salvati and Gargiulo Morelli, 2014). The 2007 recession finally determined a progressive decline in building activity (Arapoglou and Sayas, 2009). Based on the historical background, Greece is

considered an exemplificative case when investigating long-term building activity reflective of different urban cycles. The analysis was carried out at the municipal scale for the whole Greece with a specific focus on the Athens' metropolitan region, the largest city in the country.

This study analyzes official statistics of building activity derived from the most recent National Census of Population and Buildings carried out in 2011 by the Greek National Statistical Authority (ELSTAT). The total amount of buildings by number of floors and construction age was calculated for each Greek municipality; construction age was referred to 12 time periods (before 1919, 1919-1945, 1946-1960, 1961-1970, 1971-1980, 1981-1985, 1986-1990, 1991-1995, 1996-2000, 2001-2005, 2006-2010, after 2010) providing a comprehensive overview of building trends in Greece (Di Feliciantonio and Salvati, 2015).

To define relevant urban dimensions and identify significant correlations with socioeconomic local contexts, a set of background variables profiling Greek municipalities was adopted that includes: (i) percentage annual rate of population growth, (ii) population density (inhabitants/km^2), (iii) ratio of present-to-resident population, (iv) resident inhabitants per dwelling, (v-x) 6 demographic indicators (masculinity ratio, mean population age, structural dependency of population, mean household size, percentage share of singles in total population and of non-native population in total resident population), (xi) percentage share of population with third-level education in total resident population, (xii-xiii) job participation and unemployment rates, (xiv-xv) 2 indicators assessing the local-scale economic structure (percentage share of workers in industry and in services in total workforce) and, finally, (xvi) municipal area.

3.4.2. Indicators of urban growth

An index characterizing intensity, type (horizontal vs vertical), and spatial direction of growth was computed over time considering buildings with 4 (or more) floors as an expression of vertical urban expansion and buildings with 3 (or less) floors as reflecting horizontal growth. This threshold is based on the specificity of Greek settlements (average number of floors per building close to 3; e.g. Salvati et al., 2013a; Colantoni et al., 2016; Pili et al., 2017) and can be modified according to the dominant characteristics of the studied metropolitan system. This index (hereafter called 'Vertical-to-Horizontal Growth ratio', VHG) was based on a comparison between intensity of vertical and horizontal urban expansion over time:

$$\text{VHG rate: } \frac{(B^{4+})_{t+1}}{(B^{3-})_{t+1}} - \frac{(B^{4+})_{t}}{(B^{3-})_{t}}$$

where (B4+) x and (B3-) x indicates the total number of new buildings respectively with 4 (or more) floors or with 3 (or less) floors developed per year during the x-th time period (e.g. t+1: 1946-1960, t: 1919-1945). In other words, the indicator compares the intensity of urban expansion along 12 time periods each formed by two sequential time intervals (see section 2.2), identifying trends over time in the dominant (horizontal or vertical) growth component. By comparing annual building activity over two sequential time periods (t+1 and t), the VHG index is intrinsically standardized to a dynamic baseline (i.e. building activity at the t-th time interval) and assumes continuous values across the whole range of real numbers, from - ∞ to + ∞. The VHG index assumes a statistical distribution centered on zero values with positive scores indicating that settlement expansion is increasingly oriented through vertical growth. The reverse applies to horizontal growth. Zero scores

indicate stable urban expansion, with no trend toward vertical or horizontal growth. Moreover, higher scores of the VHG at municipal scale indicate a more intense (vertical or horizontal) urban expansion over time, thus illustrating spatio-temporal trends toward vertical or horizontal growth in a dynamic fashion.

An exploratory multivariate analysis was adopted with the aim to summarize trends over time in horizontal and vertical growth characterizing the Greek urban system during the last century. More specifically, a Principal Component Analysis (PCA) was run on the VHG index observed at 12 time points (see above) for each municipality in Greece (n = 326) and, separately, for a selection of Greek municipalities, i.e. those belonging to the Athens' metropolitan region (n = 59). This analysis is intended to outline the specific timing of horizontal vs vertical growth observed in Athens in respect to Greece and exemplifies the use of the VHG indicator at multiple spatial scales. The number of significant axes was chosen according to the scree-plot by selecting components with eigenvalue > 1 (Colantoni et al., 2016). Component loadings were used to identify latent relationships between variables associated with vertical and horizontal growth.

A non-parametric Spearman correlation analysis was finally run pair-wise between the municipal VHG score and each of the socioeconomic variables illustrated in section 2.2 with the aim to profile the background characteristics of each time interval characterized by distinct urbanization trends (e.g. Pili et al., 2017). After Bonferroni's correction for multiple comparisons, a p-level < 0.05 was used to identify significant pair-wise correlations.

3.4.3. Descriptive statistics and maps

Figure 3.20 illustrates trends over time in the VHG index comparing the Athens' metropolitan region with the whole of Greece. A generalized trend toward vertical growth was observed all over the study period, especially in Athens between 1919 and 2000. By contrast, a substantial stability in urban trends was observed in the period preceding World War II. The highest intensity in vertical expansion was reached in downtown Athens during 1960-1980 and 1990-2000. Conversely, vertical growth in the 2000s was particularly intense in the whole of Greece and remarkably higher than in Athens. Finally, the most recent period was characterized by a generalized trend toward horizontal expansion, more evident in the whole of Greece than in Athens. Maps in Figure 3.21 (the whole of Greece) and 22 (the Athens' metropolitan region) indicate an increasing spatial heterogeneity of the VHG index over time. Trends toward vertical growth were more evident in urban areas (Athens, Salonika, Patras, Iraklio) all over the study period, being particularly intense in peri-urban districts and rural prefectures with smaller towns during 1960-1980 and 1990-2000. These time intervals coincided with an urbanization phase characterized by intense expansion of compact and dense settlements. Taken together, the average VHG index calculated over one century (1910s-2010s) evidences urban-rural polarities in Greece, with central cities experiencing vertical growth and rural areas characterized by a mostly horizontal expansion of settlements.

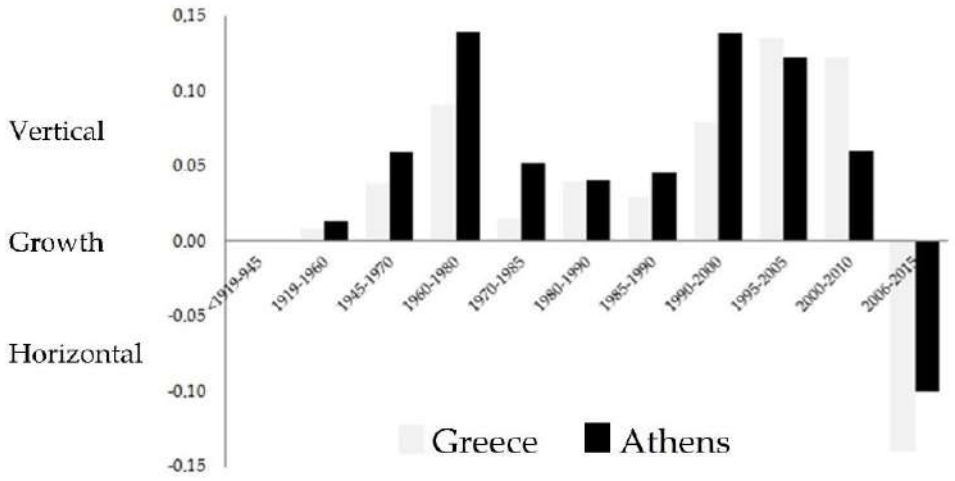
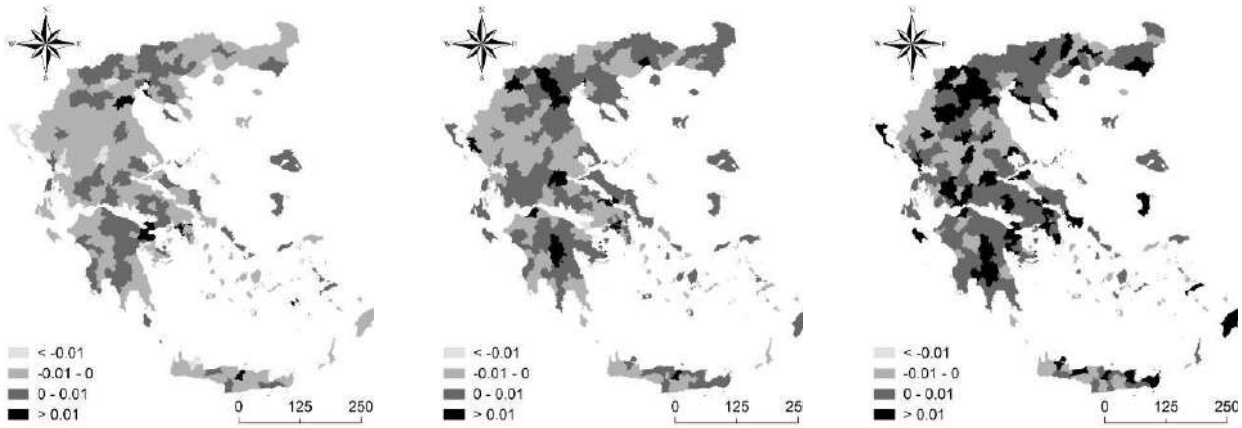
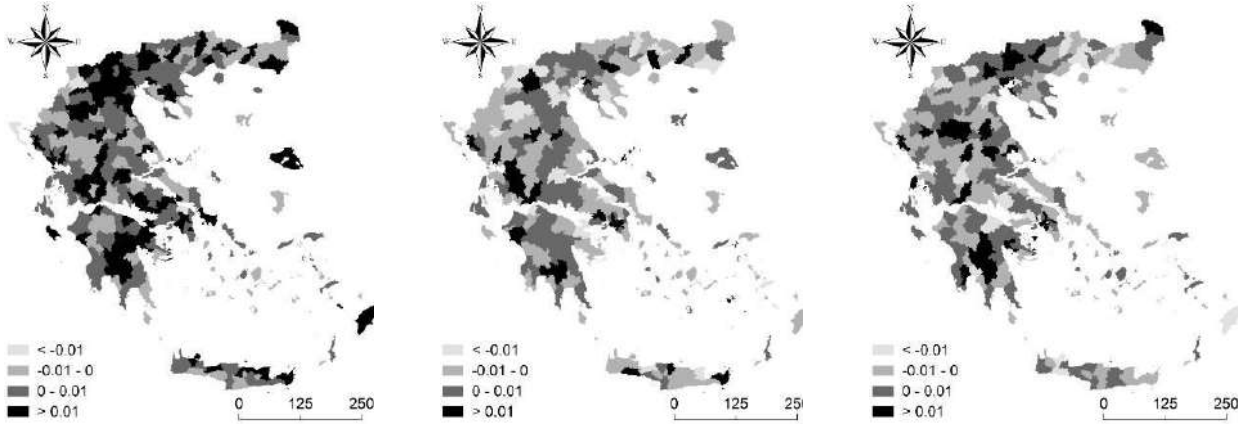


Figure 3.20. Trend over time in the ratio of vertical-to-horizontal growth of urban settlements (the VHG index) in the whole of Greece and the Athens' metropolitan region.



< 1919 - 1945 | 1919 - 1960 | 1945-1970



1960-1980 | 1970-1985 | 1980-1990

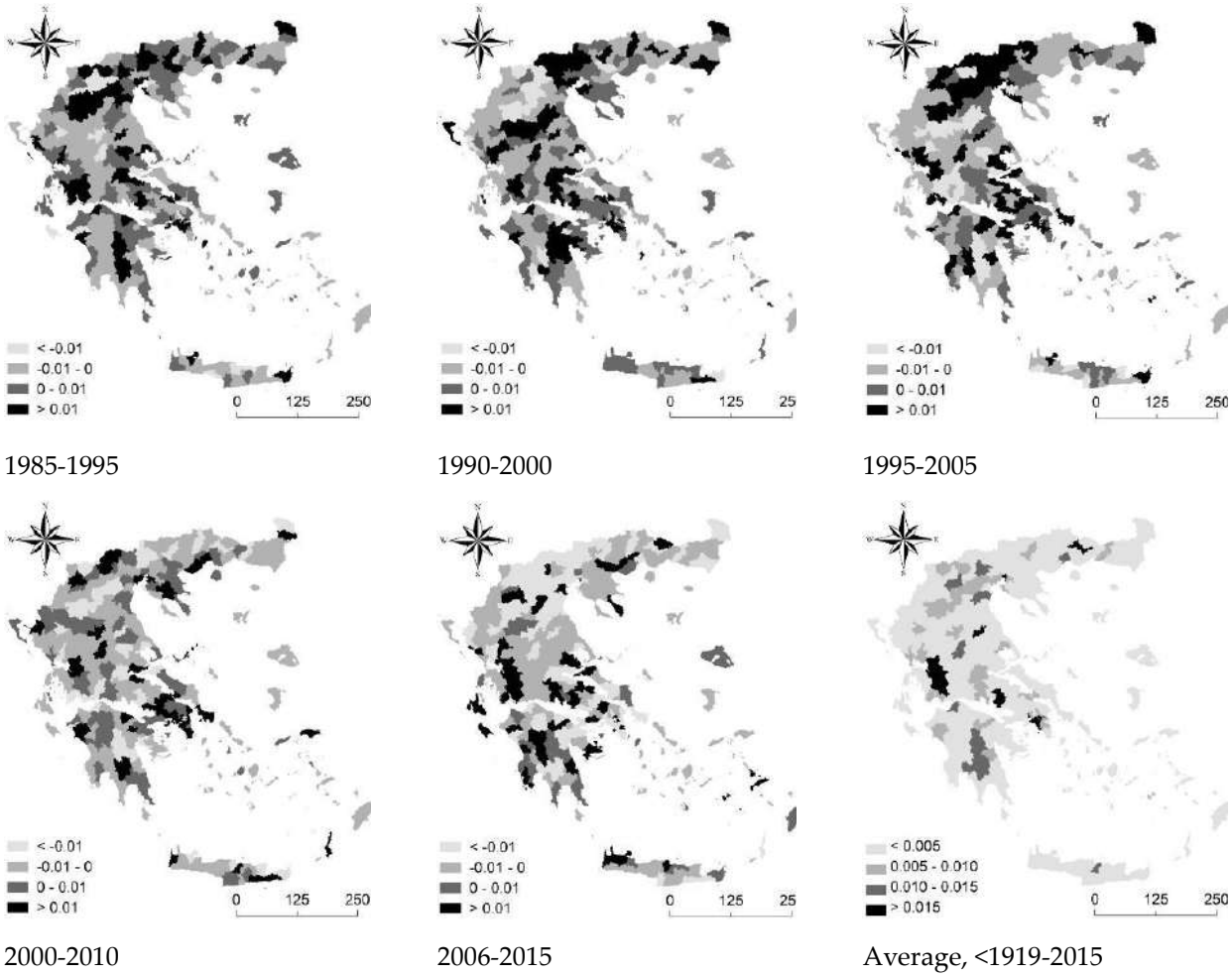


Figure 3.21. Spatial distribution of the VHG index discriminating horizontal (negative values) from vertical (positive value) growth of urban settlements in Greece, by time interval.

A latent trend toward vertical growth in Athens was more evident since 1945, outlining a strong divide between the Greater Athens' area (vertical growth) and the surrounding rural districts (horizontal growth) during 1960-1980. A more mixed expansion pattern was observed in the subsequent decades, alternating periods with vertical growth more evident in peripheral areas (1970-1985, 2000-2010) and in central locations (1990-2000, 1995-2005). Vertical growth in the most recent time interval was observed only in scattered peri-urban and rural municipalities. The largest part of the Greater Athens' area and the surrounding fringe districts were mostly characterized by horizontal growth.

Principal Component Analysis extracted 4 relevant axes explaining together 79% of the total matrix variance for the whole of Greece and 89% for the Athens' metropolitan region (Table 3.8). Positive (or negative) loadings indicate the predominance of vertical (or horizontal) growth in each examined time interval. Axis 1 (43.5% Greece, 54.4% Athens) identified a classical pattern of compact expansion encompassing a rather long time period from World War I to the late 1970s. Some recent decades (1990s and early 2000s) were characterized by relatively intense vertical growth, and contrast more recent trends toward horizontal growth (mid-2000s to mid-2010s). Vertical growth was even more intense in Athens, except for the time periods 1970-1985 and 1995-2005.

Results of a non-parametric Spearman analysis (Table 3.9) indicate a distinct correlation profile between the VHG index and selected socioeconomic variables for the Athens' metropolitan region

and the whole of Greece, confirming the value of a multi-scalar analysis of urban growth. Vertical growth at the country scale was associated positively with population density up to the mid-2000s and negatively over the following decade. Vertical growth was also positively associated with population increase between 1945 and 1980. Present-to-resident population ratio mean population age and population structural dependency index decreased with the VHG index for several time periods, except for the last time interval, where the reverse pattern was observed. Masculinity ratio, the proportion of unmarried people in total population, residents with tertiary education level, job participation rate and workers in services were all positively correlated with the VHG index up to 2005; the reverse correlation was observed for 2006-2015.

Table 3.8. Loadings of a Principal Component Analysis run on the ratio of vertical to horizontal settlement growth (the VHG index) by time interval: a comparison between the whole of Greece and the Athens' metropolitan region.

Variable	Greece				Athens' metropolitan region			
	Axis 1	Axis 2	Axis 3	Axis 4	Axis 1	Axis 2	Axis 3	Axis 4
< 1919-1945			0.60					0.82
1919-1960	0.79				0.76			
1945-1970	0.73		0.61		0.86			
1960-1980	0.87				0.91			
1970-1985		0.84				0.64	0.58	
1980-1990		0.84			0.77			
1985-1990		-0.76			0.69			
1990-2000	0.81				0.93			
1995-2005				0.67		0.71		
2000-2010	0.82				0.88			
2006-2015	-0.91				-0.94			
Variance (%)	43.5	21.0	14.3	8.9	54.4	14.7	11.7	8.5

Table 3.9. Spearman rank correlation analysis between the VHG index discriminating vertical from horizontal settlement growth and selected background variables in Greek municipalities, by time interval and zone (only significant coefficients at $p < 0.05$ after Bonferroni's correction for multiple comparisons were shown) *

Variable	<1919-1945	1919-1960	1945-1970	1960-1980	1970-1985	1980-1990	1985-1990	1990-2000	1995-2005	2000-2010	2006-2015	Average, <1919-2015
The whole of Greece												
Population density		0.46	0.65	0.65		0.29	0.27	0.38	0.36		-0.43	0.66
Population growth			0.25	0.23								0.24
Present-to-resident pop.			-0.29	-0.30			-0.29		-0.31		0.32	-0.36
Masculinity ratio		0.37	0.53	0.55			0.28	0.25			-0.36	0.55
Mean population age		-0.29	-0.46	-0.44				-0.27	-0.24		0.28	-0.46
Struct.dependency index		-0.29	-0.48	-0.46				-0.26			0.27	-0.48
Unmarried people		0.33	0.49	0.49				0.28	0.23		-0.27	0.46
Third-level education		0.37	0.65	0.62			0.25	0.31			-0.38	0.57
Job participation rate			0.41	0.40				0.23				0.33
Services		0.38	0.59	0.57				0.31			-0.37	0.51

Athens' metropolitan region										
Population density	0.61	0.70	0.68	0.47	0.62	0.62	0.69	0.59	-0.65	0.81
Population growth	-0.53	-0.68	-0.61			-0.53	-0.60	-0.53	0.67	-0.66
Present-to-resident pop.				-0.51					0.46	
Masculinity ratio	0.56	0.74	0.84							0.63
Mean population age		0.59	0.57							
Struct.dependency index	0.47	0.60	0.55						-0.48	
Average family size	-0.66	-0.88	-0.84			-0.62	-0.52	-0.50	0.67	-0.76
Third-level education			0.60							
Industry		-0.61	-0.75							
Services		0.69	0.83							0.52

* average family size, non-native residents, unemployment rate, workers in industry, and municipal size were not correlated to the studied indicators at any time period examined for the whole of Greece; unmarried people, non-native residents, job participation rate, unemployment rate, and municipal size were not correlated to the studied indicators at any time period examined for the Athens' metropolitan region

Most of the pair-wise correlations discussed above were found significant also for the Athens' metropolitan region. The most relevant differences with results from country-scale analysis were as follows: (i) population growth was negatively correlated with the VHG index, with the exception of the 2006-2015 time interval; (ii) mean population age and structural dependency index were positively correlated with the VHG index, with the exception of the 2006-2015 time interval; (iii) average family size was negatively correlated with the VHG index, with a reverse correlation for 2006-2015 and, finally, (iv) workers in industry and services were correlated (negatively or positively) with the VHG index during the most intense urbanization phase (1945-1980).

3.4.4. VHG index for sustainable contexts

Urbanization models have been shaped by mutually-interacting drivers of growth and change, being in turn influenced by agglomeration factors, accessibility, attractiveness and local competitiveness (Diappi, 2013; Kourtit et al., 2014; Amato et al., 2015; Kazemzadeh-Zow et al., 2017). With social changes, economic systems underwent fluctuations that influence building cycles and orient cities toward a new development path (Chorianopoulos et al., 2014; Taltavull de La Paz and Gabrielli, 2015; Cuadrado-Ciuraneta et al., 2017). Market dynamics, property values, housing policies and the background socioeconomic context have demonstrated to play a key role in urban expansion (Allen et al., 2004; Morris and Jonathan, 2005; Edelstein and Tsang, 2007), and justify a spatially-explicit analysis of building activity profiling urban cycles at local scale.

Spatio-temporal trends of building activity were studied here at multiple spatial scales by adopting a novel indicator of urban expansion complemented with selected background variables, allowing investigation of socioeconomic forces shaping metropolitan growth (Kasanko et al., 2006; Serra et al., 2014; Zambon et al., 2018). Due to its simplicity and precision, the VHG index discriminates vertical growth from horizontal expansion using data from censuses of buildings aggregated at the spatial scale of municipalities. Differential intensity and spatial direction of building activity (leading to a dominant vertical (or horizontal) growth) were finally correlated to socioeconomic indicators profiling the local context (Haase et al., 2010; Kroll and Kabisch, 2012; De Rosa and Salvati, 2016).

The VHG index provided an informed knowledge base to identify timing and spatial patterns of basic typologies of urban expansion in Greece. Distinct spatial patterns of building activity were observed in Greek municipalities, reflecting specific geographical gradients (e.g. urban-rural divides, coastal-inland polarization) and divergent responses to market stimuli and planning constraints (Pérez, 2010; Kourliouros et al., 2015; Papageorgiou, 2017). While intense vertical expansion coinciding with a strong population growth was observed in large urban areas (Athens, Salonika, Patras and Iraklio), a moderate vertical expansion was realized around medium-rank cities, along coastal areas and internal lowlands with small compact towns and tourism-specialized settlements. Important differences were recorded in the VHG index between Athens, the largest metropolitan area in Greece, and the whole country. These results outline how urban cycles in Greece were relatively heterogeneous over space (as in other European countries), justifying a joint analysis of intensity and spatial direction of metropolitan growth (Sarvestani et al., 2011; van den Heijden et al., 2011; Biasi et al., 2015).

In these regards, building activity and structural characteristics of settlements demonstrated to be representative of latent transformations in the geography of metropolitan expansion and decline (Barr and Cohen, 2014). Identifying territorial and socioeconomic factors that shape recent trends in horizontal vs vertical growth provides a key contribution to design and implementation of local development policies and a fine-tuning with urban planning (Delfanti et al., 2016). In this regard, the Sustainable Development Goal 11 ('Make cities and human settlements inclusive, safe, resilient and sustainable', SDG11) will inevitably place additional demands on local governments whose resources are already over-stretched by implementing existing local-level development and sustainability initiatives (Klopp and Petretta, 2017). However, very few effective linkages have been identified between SDG11 and existing local-level policies for sustainable development, further increasing the challenge posed by SDG11 implementation (Patel et al., 2017). The success of the SDG11 depends on the availability and accessibility of robust data and reliable indicators of metropolitan growth, providing basic and advanced knowledge to governance systems that can catalyze urban transformations (Almeida et al., 2018). By producing an advanced knowledge of different urban cycles and types of metropolitan expansion, the VHG index may effectively contribute to the success of the SDG11.

3.5. Emerging urban centrality for monitoring city growth and polycentric development

Urban expansion is inherently related to the economic base and the socio-spatial structure of a given region, reflecting territorial complexity and local competitiveness at the same time. Initially concerning the United States, urban dispersion has advanced rapidly in Europe, becoming a debated issue in research, planning and political agendas (Galster et al., 2001; Richardson and Chang-Hee, 2004; Bruegmann, 2005; Kasanko et al., 2006; Orenstein et al., 2014). While representing interesting examples of compact and dense cities, European urban agglomerations have experienced massive land consumption rates thanks to the sprawled expansion of residential settlements into peri-urban areas (European Environment Agency, 2006). This process has consolidated large conurbations and medium-size town networks at the same time (Paul and Tonts, 2005; Schneider and Woodcock, 2008; Salvati, 2014a; Serra et al., 2014).

Local development paths have important implications in the spatial organization of metropolitan regions promoting (more or less) marked shifts towards discontinuous and entropic urban patterns (Tsai, 2005; Turok and Mycknenko, 2007; Colantoni et al., 2016). For example, a spatially-balanced and functionally-polycentric metropolitan structure characterized by population decentralization and the coexistence of multiple sub-centers, may contribute significantly to urban competitiveness (Phelps et al., 2006; Caruso et al., 2007; Gilli, 2009; Herrschel, 2009; Lang et al., 2009; Fernandez Maldonado et al., 2013; Salvati et al., 2015a).

Cited article

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The notion of entropy, traditionally associated with the concept of “disorder", was first considered in the geography literature by Batty (1974). Entropy was largely used in the assessment of regional economic systems (Gordon, 2010; Wilson, 2010) with relevant implications in the analysis of patterns and processes of urban growth (Batty, 2010). Cabral et al., (2013) provided a comprehensive definition of "spatial entropy". In recent years, based on the integration of remote sensing, satellite data and geographic information systems, entropy-based indicators such as Shannon diversity or Pielou evenness have been increasingly used to measure sprawl, assessing distribution and concentration of settlements and urban sustainability (Yeh and Li, 2001; Joshi et al., 2006; Araya and Cabral, 2010; Battha et al., 2010; Sarvestani et al., 2011; Deka et al., 2012). The notion of entropy has been also associated to the social sphere when investigating e.g. the impact of discontinuous urban expansion on local demographic and economic contexts (Maly, 2000). According to Lee (2011), unbalanced and fragmented socioeconomic contexts are more likely observed in sprawling areas than in consolidated cities. Sprawl patterns reflect social homogenization (or segregation) and loss of community interactions (Le Goix, 2005; Brueckner and Largey, 2008; Arapoglou and Sayas, 2009). Finally, sprawl-driven changes in the use of land have caused negative impacts on natural habitats and cropping systems, with loss of agricultural and natural land as a result of dispersed urbanization (Bart, 2010; Wilson and Chakraborty, 2013; Peng et al., 2015; He et al., 2015).

Previous studies have considered the spatial diversification in the level of land imperviousness as a proxy of urban hierarchy at the metropolitan scale (Munafò et al., 2010). Entropy-based

functions have been proposed to evaluate heterogeneity in the composition of land imperviousness in European metropolitan regions (Salvati, 2013). Such functions identify inner cities and sub-centers comparatively better than population density or land-use indicators (Tombolini et al., 2015). Based on these assumptions, diversification in land imperviousness can be considered a low-level property of complex urban systems with environmental and socioeconomic implications (Salvati and Carlucci, 2016).

A wide set of socioeconomic indicators were used to investigate, characterizing local contexts with different levels of land-use diversification in three southern European metropolitan regions: Barcelona, Rome and Athens. Southern Europe has been recognized as a homogeneous region as for metropolitan structures and urban morphologies (Leontidou, 1996; Gospodini, 2009; Salvati and Gargiulo Morelli, 2014). Since World Word II, the expansion of Mediterranean cities has been the result of consecutive waves of dense and dispersed urbanization forming polarized metropolitan regions which contrast, in some ways, with the urban continuum typical of northern and western Europe (Delladetsima, 2006; Catalàn et al., 2008; Chorianopoulos et al., 2010). Mediterranean cities express a sort of socioeconomic dualism between compact and diffused urban models and represent paradigmatic examples of transitional and entropic cities featuring a socioeconomic structure based on traditional services with sparse economically-dynamic and socially-mixed districts (Couch et al., 2007).

Barcelona, Rome and Athens have undergone scattered urban patterns as a result of differentiated development processes (Di Feliciantonio and Salvati, 2014). Sprawl has adapted to each context in different ways, depending on historical, cultural and political issues and producing distinct socio-spatial models (Salvati and De Rosa, 2014). The notion of entropy is particularly relevant in these contexts as a result of complex and hardly predictable urban patterns and processes (Couch et al., 2007). Evenness-based indexes contribute to identify scattered or polycentric expansion paths based on the spatial segregation in the use of land along urban gradients (Encarnaçao et al., 2013).

Shannon diversity (H') and Pielou's evenness (J) indexes were used to assess the diversification in the degree of land imperviousness at the local scale. These indexes reflect the stratification of different intensities of land imperviousness as a result of a mixed distribution of land-uses typical of cities with advanced and diversified functions. The highest values of these indexes are associated to central cities and polycentric sub-centers hosting dense population, upper economic functions and typical socio-spatial patterns. Transitional sprawling areas are hypothesized to share intermediate evenness values between urban and rural areas.

3.5.1. An entropy-based indicator for monitoring urban development

Three metropolitan regions in southern Europe (Barcelona, Rome and Athens) were investigated. These cities share a hyper-compact morphology, settlement informality and social diversification. These attributes reflect the deregulated expansion of the 1960s and 1970s which has determined social stratification and economic homogenization at the same time (Garcia and Riera, 2003; Arapoglou and Sayas, 2009; De Muro et al., 2011). The three study areas encompass the European Urban Atlas boundaries identifying the Large Urban Zones of Barcelona, Rome and Athens (European Environment Agency, 2011) and coincide with relevant administrative units: (i) the metropolitan region authority for Barcelona, (ii) the newly appointed metropolitan city authority

for Rome, and (iii) the administrative regional authority for Athens. The Barcelona metropolitan region covers nearly 3600 km^2 with undulated topography consisting of 25% lowlands, 60% uplands and 15% mountains. The Rome metropolitan region covers nearly 5300 km^2 with undulated topography consisting of 35% lowlands, 50% uplands and 15% mountains. The Athens metropolitan area extends more than 3000 km^2 consisting of mountains bordering Athens, three coastal plains (Messoghia, Marathon and Thriasio) and the island of Salamina. Each study area presents a different demographic and economic structure: advanced services, including real estate and finance, tourism and manufacturing in Barcelona; tourism, commerce and the public sector in Rome; manufacturing and more traditional services, commerce and construction, in Athens.

3.5.2. Defining the elementary spatial unit

Taken as administrative boundaries largely used in urban studies, municipalities and urban districts were chosen as the elementary spatial unit for this study (Salvati, 2014a). In Spain, Italy and Greece, municipalities are the minimum mapping unit of most statistical surveys and allow reliable comparisons with indicators derived from official data sources. A total of 164 and 115 municipalities were considered in Barcelona and Athens, respectively. Rome metropolitan city authority was partitioned into 235 spatial units with 121 municipalities, including the central municipality of Rome (1285 km^2) divided into 114 urban districts with a size comparable to the surrounding municipalities. Spatial units were classified in four categories: 'central city', 'urban area', 'sub-centers' and 'peri-urban area'. The central city corresponds to the inner municipalities of Barcelona and Athens and to the urban districts of Rome including the historical city and the surrounding consolidated area. The urban area corresponds to the Barcelona metropolitan area, to the Greater Athens area and to the remaining part of the Rome municipality. Sub-center municipalities were defined in the three areas according to Salvati and De Rosa (2014). Peri-urban areas include the remaining municipalities surrounding each central city.

3.5.3. Mapping land imperviousness

Impervious land is defined as constituted by pavement structures such as roads, sidewalks, driveways and parking lots that are covered by asphalt, concrete, brick, stone and rooftops (European Environment Agency, 2006). The European Environment Agency (EEA) has recently produced a raster map of built-up and non-built-up areas including continuous degree of land imperviousness ranging from 0 to 100% in 100 x 100 m spatial resolution with pan-European coverage (European Environment Agency, 2011). The map has been derived from elaboration on multi-sensor and bi-temporal, ortho-rectified satellite imagery referring to 2006 and is disseminated in GeoTiff format with an overall accuracy higher than 85% per hectare and omission and commission errors consistently below 15%. High-resolution Google Earth imagery was used to validate this map obtaining reference values across a 10 x 10 m grid positioned around the sampling points (European Environment Agency, 2011).

3.5.4. Indicators of land imperviousness and contextual indicators

The composition of impervious land in each spatial unit was estimated by computing the percent surface area of 11 cover classes (0%, 1-10%, 11-20%, ..., 91-100%) in the total surveyed area. The 'Tabulate area' tool provided with ArcGIS (ESRI Inc., Redwoods, USA) was used for calculation by overlapping the land imperviousness map and the shapefile representing boundaries of the elementary spatial units. The 'Tabulate area' procedure computes descriptive statistics such as count

of the raster values recorded on each 100 x 100 m cell belonging to each spatial unit. Shannon diversity index (H') and Pielou evenness index (J) were applied to the composition of sealed land in each spatial unit to measure diversity in the profile of land imperviousness at the local scale. Shannon H' was calculated by computation on the proportion of each cover class in the total surface area (pi) as

$$H' = - n_i=1\ p_i \log p_i$$

Pielou J was calculated as:

$$J = H'/H_{max}$$

where Hmax is the logarithm of the number of cover classes with non-null surface area. Pielou J ranges between 0 and 1 and could be considered an indicator of urban centrality with the highest values typically observed in central cities (Salvati, 2014a). Local-scale data primarily was used released by the national statistical authorities of Spain (INE), Italy (ISTAT) and Greece (ELSTAT) and other official sources to develop 52 contextual indicators (Table 3.10) classified into seven domains (population dynamics: 3 indicators; demographic structure: 5; built-up settlements: 7, education and labor market: 6; economic structure: 6; territory and topography: 5; urban land-use: 10; forest land-use: 10). Indicators included specific descriptors of urban expansion investigating place-specific relationship between morphology and socioeconomic functions. The indicators of urban land-use were derived from the land imperviousness map described above. The forest land-use indicators were derived from the 100 m-resolution raster maps provided by Hansen et al., (2013) which assessed percent forest land by density class in each spatial unit.

Table 3.10. List of contextual indicators used.

Name	Measurement unit	Year	Source
Population dynamics			
Population density	Inhabitants per km^2	2011	Census of population
Annual population growth rate	%	2001-2011	
Annual population growth rate	%	1981-2011	
Demographic structure			
Elderly index	% population > 65 years	2011	
European (non-native) residents	% of total resident foreigners		
European (non-native) residents	% of total resident population		
Average number of household components	Family size		Census of households
Families with one component	% of total households		
Urban settlements			
Buildings developed before 1950	% of total building stock	1951	Census of buildings
Buildings developed before 1980	% of total building stock	1981	
Building density (1980)	Buildings per inhabitant		
Building density (1990)	Buildings per inhabitant	1991	
Building density (2000)	Buildings per inhabitant	2001	
Density of dwellings	Dwellings per building	2011	
Density of rooms	Rooms per dwellings		
Education and labor market			
Population with tertiary education degree	% of total resident population	2011	Census of population
Illiterate population			
Unemployment rate			
Job participation rate			
Share of entrepreneurs in total workers			
Share of employees in total workers			

Economic structure			
Workers in agriculture	% of total workers	2011	Census of population
Workers in industry			
Workers in commerce			
Workers in transport			
Workers in bank, finance, insurance sectors			
Workers in public sector			
Territory and topography			
Average per-capita declared income	Euros	2011	Administrative register
Distance from the central city	km		Territorial statistics
Mean elevation	m		
Proximity to the sea coast	Dummy (0: internal; 1: coastal)		
Surface area of each spatial unit	km^2		
Urban land-use			
1-10% impervious land	% of total area	2006	EEA (2011)
11-20%			
21-30%			
31-40%			
41-50%			
51-60%			
61-70%			
71-80%			
81-90%			
91-100%			
Natural land-use			
1-10% forest cover	% of total area	2012	Hansen et al. (2013)
11-20%			
21-30%			
31-40%			
41-50%			
51-60%			
61-70%			
71-80%			
81-90%			
91-100%			

Descriptive statistics and maps were prepared to illustrate the spatial distribution of Pielou J evenness index at the local scale. A Principal Component Analysis (PCA) was run separately for each city on the data matrix composed by 54 input variables (52 contextual indicators and the two indexes of entropy in the spatial distribution of land imperviousness, Shannon H' and Pielou J) made available for each elementary spatial unit. The PCA was aimed at identifying socioeconomic indicators associated to sprawled or polycentric patterns of urban expansion. Significant components with eigenvalue > 3 were selected according to the PCA correlation matrix. A non-parametric Spearman rank correlation analysis was implemented to assess the relationship between Pielou evenness J index and the share of impervious land (or forest land) in the total surveyed area. Significance was tested at $p < 0.05$ after Bonferroni's correction for multiple comparisons.

3.5.5. Results from entropy-based indicator

The spatial distribution of Pielou J index was calculated for each investigated city by urban zone (Table 3.11). The indicator reaches the highest values in central cities, especially in Rome and Barcelona. On average, sub-centers have a higher value of the J index than urban areas in Barcelona

and a lower value in Rome and Athens, sharing a moderate variability in all metropolitan regions, excepting sub-centers in Athens. Peri-urban areas assume the lowest values in all cities (0.42 in Barcelona, 0.15 in Rome and 0.41 in Athens) with a relatively high variability, especially in Rome. The spatially-heterogeneous distribution of the J index in the three cities outlines the different configuration of each metropolitan region (Figure 3.1). Rome and Athens have a more centralized structure than Barcelona with inner cities showing the highest diversification in land imperviousness, declining in the case of sub-centers. However, Rome's structure is generally denser and more concentrated compared to Athens, where distinct clusters of municipalities with J values above 0.8 were observed within the consolidated urban area. By contrast, the structure of Barcelona metropolitan region reflects a moderately polycentric configuration, with clusters of municipalities physically independent from the central city and totalizing J values above 0.8.

Table 3.11. The spatial distribution of the Pielou J index assessing diversification of land imperviousness in the three cities (median±coefficient of variation (CV) for each group of municipalities/urban districts).

Indicator	Barcelona		Rome		Athens	
	Median	CV	Median	CV	Median	CV
Central city*	0.89	-	0.91	-	0.78	-
Urban area	0.62	0.38	0.80	0.35	0.82	0.17
Sub-centers	0.79	0.12	0.65	0.24	0.76	0.99
Peri-urban area	0.42	0.59	0.15	0.78	0.41	0.61

* Represented by one central municipality (or district).

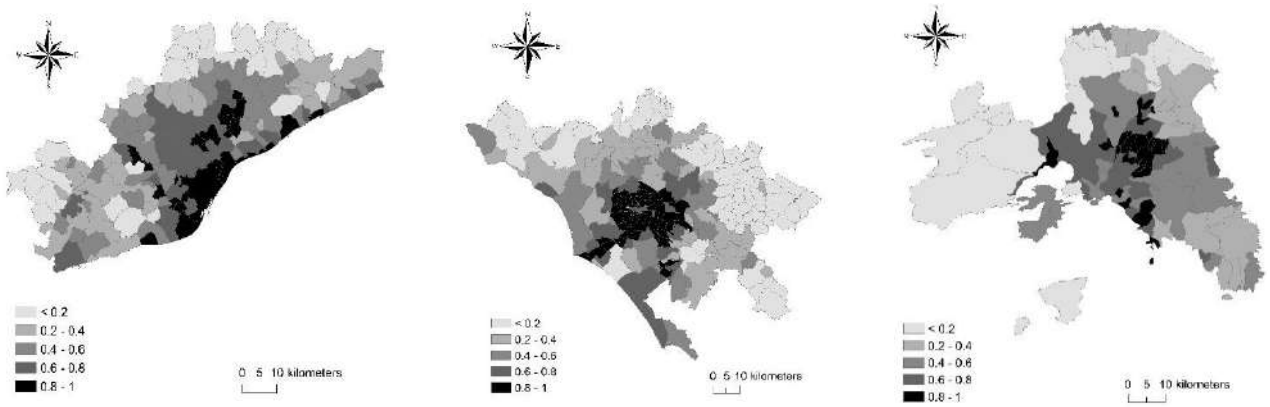


Figure 3.1. The entropy-based indicator of urban centrality in the three investigated cities (left: Barcelona; middle: Rome; right: Athens).

Principal Component Analysis investigates the socioeconomic structure associated to different levels of diversification in land imperviousness (Table 3.12). Component 1 is the only associated to Shannon H' and Pielou J indexes in all cities investigated, explaining 32%, 37% and 30% of the total variance respectively in Barcelona, Rome and Athens and producing a coherent structure of component loadings (16 variables out of 35 are (positively or negatively) associated to component 1 in all cities). Positive loadings were observed for Shannon H', Pielou J, population density and the percentages of impervious land between 41% and 90%. Negative loadings were observed for the distance from the inner city, per-capita number of buildings, and the percentages of forest cover between 31% and 80%. Neither Shannon H' nor Pielou J are correlated with the surface area of municipalities or urban districts. This result suggests that indexes of diversification in land imperviousness are independent from the size of the elementary spatial unit in all cities considered.

Negative loadings to component 1 were observed in Rome for mean elevation and the percentage of European, non-native residents. Per-capita income, job participation rate, employees in credit, insurance and business sectors, number of families per resident population and number of rooms per dwelling had positive loadings to component 1. The share of employees in total population was positively correlated with component 1 in both Barcelona and Rome. The share of employees in the primary sector was negatively correlated to component 1 in Athens. Finally, the ratio of dwellings per building was positively correlated to component 1 in both Barcelona and Athens.

Spearman rank correlations between Pielou J index and land imperviousness (or forest cover) profile in each spatial unit (Figure 3.22) confirms the results illustrated above and derived from the PCA. The evenness index was correlated positively with the percentage of impervious land and negatively with the percentage of forest land. The highest (positive) correlation coefficients were found for land imperviousness classes ranging between 21% and 100% in Barcelona, 11% and 90% in Rome, 41% and 90% in Athens. The highest (negative) correlation coefficients were found for forest land cover between 31% and 80% in Barcelona, 31% and 100% in Rome, 1% and 90% in Athens.

Table 3.12. Principal Component Analysis: loadings (> |0.5|) on the relevant component for each city.

Variable	Barcelona	Rome	Athens
Distance from the central city	-0.60	-0.89	-0.82
Mean elevation		-0.84	
Population density	0.70	0.60	0.79
Average number of household components			-0.69
Average per-capita declared income		0.76	
Building density (1990)	-0.65	-0.75	-0.72
Building density (2000)	-0.77	-0.69	-0.74
Job participation rate		0.62	
Share of employees in total workers	0.68	0.84	
European (non-native) residents		-0.62	
Workers in agriculture			-0.65
Workers in bank, finance and insurance sectors		0.77	
Population with tertiary education degree		0.67	
Density of dwellings	0.63		0.67
Density of rooms		0.66	
1-10% forest cover			-0.71
21-30%			-0.64
31-40%	-0.65	-0.66	-0.71
41-50%	-0.67	-0.59	-0.62
51-60%	-0.70	-0.73	-0.60
61-70%	-0.64	-0.61	-0.66
71-80%	-0.64	-0.79	-0.61
81-90%		-0.77	-0.63
91-100%		-0.79	
11-20% impervious land		0.65	
21-30%	0.65	0.73	
31-40%	0.81	0.81	
41-50%	0.82	0.82	0.60
51-60%	0.88	0.84	0.67

61-70%	0.89	0.80	0.74
71-80%	0.86	0.78	0.77
81-90%	0.86	0.72	0.65
91-100%	0.76		
Shannon H' diversity	0.92	0.94	0.83
Pielou J evenness	0.92	0.97	0.83
Explained variance (%)	31.9	37.0	29.8

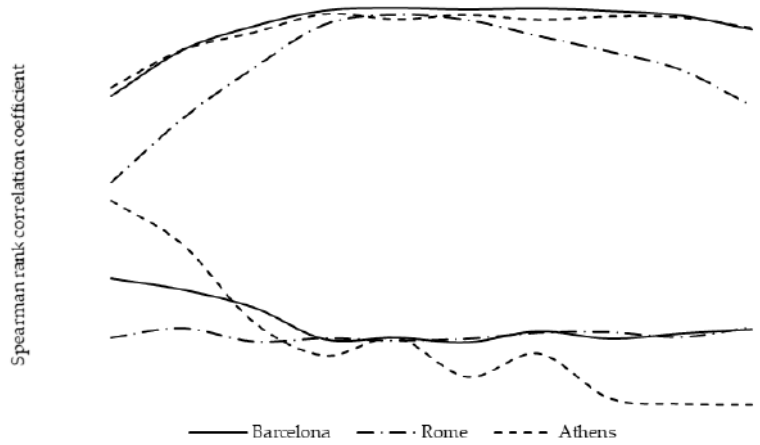


Figure 3.22. Spearman rank correlation between the entropy-based indicator and the percentages of land imperviousness (positive coefficients) and forest cover (negative coefficients) in the three metropolitan areas. The area respectively above (or below) the positive (or negative) horizontal dashed lines indicate significant Spearman rank coefficients at $p < 0.05$ after Bonferroni's correction for multiple comparisons.

3.5.6. Urban centrality and changes in the metropolitan hierarchy

Since urbanization is an effective driver of landscape transformations, contemporary cities are frequently characterized by an irregular and entropic distribution of land-use (Huang and Chen, 2007; Caruso et al., 2007; Song and Knaap, 2007; Sun et al., 2007). Metropolitan systems develop following path-dependent factors triggering together morphological and functional changes (Salvati and Carlucci, 2016). Urban complexity is at the same time the result of heterogeneous patterns of growth, e.g. stimulated by deregulated and dispersed urban expansion, and of non-linear changes in the economic structure of metropolitan region, e.g. driven by polycentric development (Gordon et al., 1986). It has been widely demonstrated how planned or deregulated urban scattering creates multiple interrelationships between urban form and economic functions (Arribas-Bel et al., 2011; Xu et al., 2013; Haase et al., 2014). For example, sprawl patterns frequently result in territorial models with irregular configurations and heterogeneous socioeconomic traits (Mann, 2009; Siedentop and Fina, 2012; Salvati, 2013; Oueslati et al., 2015).

Approaches based on indicators of land imperviousness provide relevant information on structural changes in metropolitan regions (Couch et al., 2007). According to Tombolini et al., (2015), the (non-linear) relationship between sprawl and diversification in the use of land reflects urban complexity and a fragmented peri-urban landscape. A mixed use of land is the result of urban concentration and changes in the localization patterns of advanced functions. Salvati (2014) demonstrates that land-use diversity can be effectively estimated through the analysis of diversity in the levels of land imperviousness observed at a given spatial scale. However, place-specific morphologies and functions contribute to uneven polarization in central cities and peripheral

districts, altering the diversified structure of mono-centric cities along urban gradients (e.g. Kroll and Kabisch, 2012; Haase et al., 2013).

This study proposes an empirical and comparative investigation of socioeconomic local contexts characterized by different profiles of land imperviousness reflecting multiple land-use patterns within three metropolitan regions of southern Europe. Pielou J index was considered as a proxy of urban centrality and polycentric expansion, since sub-centers have similar characteristics with inner cities in terms of land imperviousness profile (Salvati and Carlucci, 2016). High degrees of evenness in land imperviousness are concentrated in urban districts, where a greater heterogeneity in the use of land is expected in respect to rural areas. The highest values of Pielou J index in all cities are observed in areas with upper economic functions and population concentration. Central cities and sub-centers have similar values of the Pielou J index, suggesting that entropy-based indicators can be more effective in the assessment of urban centrality than demographic or land-use indexes. This is especially true in spatially-complex socioeconomic contexts with both scattered or polycentric expansion (Salvati, 2014a). With urban expansion being a result of similar demographic patterns, the metropolitan regions of Barcelona, Rome and Athens differ in both urban form and socio-spatial structure (Salvati, 2013). After experiencing a moderate expansion until the 1950s and a massive demographic increase during the subsequent two decades up to a slowdown in population growth since the early 1980s onwards, the existing urban structures appear to be quite different, spanning from a moderate polycentrism in Barcelona to a prevalently mono-centric structure in Athens (Salvati and De Rosa, 2014). While dispersed urbanization is a common trait in all cities investigated, place-specific factors influenced the regional organization of Barcelona, Rome and Athens in a different way (Mudu, 2006; Garcia-Lopez and Muñiz, 2010). In Rome, indexes of diversification and evenness in the level of land imperviousness are intimately associated with high per-capita income and job participation rate, skilled labor force and concentration of workers in advanced services, indicating that upper economic functions still concentrate in the central city (Munafò et al., 2010). Scattered urban expansion in Rome has been mainly driven by population increase and residential suburbanization, with a lower impact of industrial delocalization processes than in Barcelona (Tombolini et al., 2015). A negative correlation with the percentage of workers in agriculture was observed in Athens suggesting that diversity in the use of land is mainly oriented along the urban gradient (Arapoglou and Sayas, 2009). This evidence outlines the persistence of a mono-centric spatial organization in the Athens metropolitan region (Gospodini, 2009). Finally, a positive correlation with the ratios of dwellings per building and of employees in resident population was observed in Barcelona, possibly reflecting a spatially-balanced and moderately polycentric metropolitan structure based on compact but discontinuous settlements. Sub-centers with high diversity in land imperviousness have grown at gradually higher distances from the central city, concentrating population and economic activities (Muñoz, 2003). The Pielou evenness index applied to land-use diversity allows a comparative investigation in the spatial structure of metropolitan regions, monitoring changes in the metropolitan hierarchy and identifying the socioeconomic factors most associated to entropic urban contexts (Chen, 2008; Encarnaçao et al., 2013; Mohajeri et al., 2013). The distinct development paths observed in the three southern European metropolitan areas produced mixed urban patterns with some comparable features in terms of spatial structure and place-specific traits influenced by the differential localization of economic activities (Cavailhes et al., 2004; Caruso et al., 2007; Frenkel and Ashkenazi, 2008).

3.6. Urban encroachment, land-use and demographic change

The widespread expansion of urban areas seems a persistent process in both developed and emerging countries (Kazemzadeh-Zow et al., 2016). With the consequent transformation of pristine land-use, urban sprawl is currently one of the major and threatening urbanization trends affecting the land resource. Specifically, dispersed settlement dynamics have involved a sharp acceleration in exploitation of agro-forest soils, invading and fragmenting areas with high natural and rural value (Zambon et al., 2015, 2017). Several factors associated with low-density urban expansion have been analyzed to define a set of appropriate indicators to investigate sprawl processes (Biasi et al., 2015; Colantoni et al., 2016; Cuadrado-Ciuraneta et al., 2017).

Land consumption, indicating a continuous and larger tendency resulting from the continuous sealing of pervious soils whose availability, has been particularly reduced in recent decades. This has led to new and irreversible forms of territorial and landscape transformations (Delfanti et al., 2016). Soil formation is linked to a slow process of decomposition of the surface rocks of the earth's crust. For this reason, soil should be considered as a limited and non-renewable natural resource (Barberis, 2005; European Commission, 2004). After a stress event (as natural disasters), soil takes a long time to regenerate and restore its biodiversity, also causing a drastic degradation of natural ecosystems, a progressive change in the ecological balance, increased erosion phenomena and fragmentation of habitats (Johnson 2001; Eurostat 2003; European Commission, 2004; Barberis, 2005; EEA, 2006; Scalenghe and Ajmone Marsan, 2009; Munafò et al., 2003, 2011b).

Cited article

Tombolini, I., Zambon, I., Rontos K., Salvati, L. (2018). Urban Encroachment, Land-Use And Demographic Change. International Journal Of Ecological Economics & Statistics, 39(4).

Investigating the main land-use dynamics worldwide revealed a progressive decrease of surface area intended for agricultural use, although the latter is often particularly fertile (Ferrara et al., 2014). Land loss is accompanied by the increase in both artificial areas, wooded areas and semi-natural environments and a parallel decrease of cropland (EEA 2004, 2010). According to the Corine Land Cover project data, almost 90% of land-use changes between 1990 and 2000 is due to the loss of agricultural areas due to (i) new urbanization or (ii) the phenomenon of land abandonment, with subsequent reforestation. At the same time, more than 80,000 ha in Italy were "artificially constructed" through the development of new residential, industrial and commercial areas, services, mining areas, road and railway networks (Munafò et al., 2004; Maricchiolo et al., 2005).

Closely related to land consumption, soil sealing defines the change of land by permanent covering with materials (e.g. concrete, metal, glass, asphalt and plastic) for the construction of buildings, roads or other uses, resulting in new territorial forms and landscape transformations that can be explained as "irreversible" (Grenzdorffer, 2005; EEA, 2006; Munafò et al., 2011a). Sealing concerns not only urban areas, but also agricultural, natural and semi-natural zones, representing the most noticeable procedure of land consumption as a real process of soil degradation (Montanarella, 2007; Scalenghe and Ajmone Marsan, 2009; Munafò et al., 2010). For instance, soil sealing reduces the hydrological control capacity of the soil, increasing the risk of flooding and erosive phenomena with consequent transport to natural and artificial deposits of large amounts of sediment and contaminants (Fumanti, 2009).

Moreover, soil consumption manifests itself in the forms of extension of the urban edge, with the creation of new urban environments (Munafò et al., 2011a; De Rosa and Salvati, 2016; Pili et al., 2017). However, the current expansion of sealing surfaces is largely attributed to unplanned urban development, which mixes different types of land-use in urban and peri-urban fringes (EEA, 2006).

In the Mediterranean region, many urban areas have progressively lost their compactness, evolving towards a wider pattern due to a changed form of residential, commercial and infrastructure expansion (Leontidou, 1990; Catalàn et al., 2008; Munafò et al., 2010). This has produced a subtle progression of simplification and deterioration of the rural landscape owing to the reduction or disappearance of wooded areas, arable land and vineyards (Polyzos et al., 2008; Salvati et al., 2012). In Italy, in the presence of suboptimal territorial planning tools, both at municipal and regional levels, especially in southern regions, but also in Veneto and Latium (Istat 2009), urban dispersion has been more intense, producing a strong territorial metropolization and a consequently high rate of soil consumption.

Urban sprawl represents a peculiar constituent of vast areas in Italy, where it has removed the distinction between cities and countryside, leading to high socioeconomic and environmental costs. In the 1960s-1970s, the typical expression of the "demographic boom" was associated with a compact and dense growth of central cities. Since the 1980s, urban sprawl took pace thanks to the cultural transformation of population expectations in relation to other factors related to life quality and, particularly, to the spreading of economic well-being. Choosing to live at considerable distances from the city center was also supported by the development of transport infrastructures that allowed fast daily travels between the place of residence and work (or study). Other influences that determine the increase of residential areas in peri-urban areas were attributable to the low costs of real estate units.

Two kinds of urban growth exhibit very different soil consumption rates and characteristics. Compact growth involves almost total saturation and natural soil sealing; conversely, a dispersed city is characterized by the coexistence of buildings and green areas, which guarantees a partial persistence of natural features. These two categories also differ in the degree of fragmentation that they exert outside the strictly urban areas. While impacts on peripheral fringe areas due to "compact" urban extensions are relatively small, in the case of sprawl, a substantial part of the urban margin is taken away from the original use due to fragmentation (Duany et al., 2000; Terzi and Bolen 2009; Frondoni et al., 2011; Munafò et al., 2011a).

3.6.1. Monitoring urban sprawl and land consumption in Italy

The most significant data collection at the national level that reconstructs the patterns of soil consumption from the post-war period up to nowadays is derived from a survey of Institute for Environmental Protection and Research (ISPRA). Its work was structured in three main phases: (i) photo interpretation; (ii) integration of local data with Earth observation data at European level; and (iii) elaboration of the related indicators. During the photointerpretation, 120,000 points of a layered three-level network (national, regional and municipal) were monitored throughout the Italian territory. This tracking allowed to exceed the limit of the smallest cartographic unit typical of thematic cartography, which would not allow to consider artificial surfaces below these minimum detection units.

Cartographic analysis was based on the comparison of the historical data available. The collected information has therefore been confirmed (or possibly corrected) in the validation phase. To verify the degree of correspondence between data interpretation and validation data, a thorough evaluation of the survey accuracy was carried out. Global accuracy defines the percentage of accuracy of a classification relative to the reality:

$$\text{Global Accuracy} = N / Tot$$

where N = number of correctly classified points (sum of the main diagonal of the error matrix); Tot = total points.

The user's accuracy defines how many points attributed to class "I" are in that class:

$$UA = a_{ii} / R_i$$

where UA = User Accuracy or User Accuracy; a_{ii} = number of correctly classified points of class i; R_i = line total i.

The accuracy from the point of view of the producer defines how many points belongings to reality to class i are classified into that class:

$$PA = a_{ii} / C_i$$

where PA = Producer Accuracy; a_{ii} = number of correctly classified points of class i; C_i = total of column i.

For the calculation of the indicators, a binary scaling method was adopted, identifying the areas unsealed with the code "0" and the areas sealed with "1". The percentage of soil consumed was calculated as the value of "0" and "1" (expressed as a percentage) for each time point. Two indicators have been derived: (i) "total consumed area", multiplying the amount of soil consumption for the surveyed area; and (ii) "per capita soil consumption" by dividing the surface area consumed (m^2) by resident population.

This study outlines a continuous increase in sealed soil during the study period, from 2.8% (8289 km^2) in 1956 to 6.9% (20691 km^2) in 2010. The phenomenon was more rapid at the end of the 1990s (average land consumption amounted to 9.2 m^2 per second). However, even recently, soil consumption was quite accelerated (more than 70 ha per day). At the regional level, the highest values of sealed soils have been recorded in northern Italy and, above all, northwest regions. In 1956, soil consumption was medium-low (less than 4.5%) in many regions of Italy. In 2010, most of the administrative regions of Italy (14 out of 20) were overpassed the critical threshold of 5% of the total land sealed. Lombardy region is the one that sums the largest consumed area (more than 10% of the total land). Significant increases in sealed surfaces were found in Emilia Romagna, Latium and Sicily regions. Even at the municipal level, soil consumption was high, with a growing trend in recent years (ISPRA, 2012). It is necessary to highlight, however, how the percentage values are not significant unless compared to the absolute values. This depends on the fact that the relationship between urban area and territorial extension varies considerably from city to city. There are municipalities, such as Rome, which have a very large territorial extension to the urban area; while, in others such as Milan, Naples and Turin, the consolidated city has exceeded the administrative limits of the central municipality. In the first case, relatively high values of soil consumed in absolute terms may account for low percentages due to the presence of large agricultural or natural areas

around the city. In the second case, the municipal area has been urbanized with percentages that also exceed 60% of the administered area.

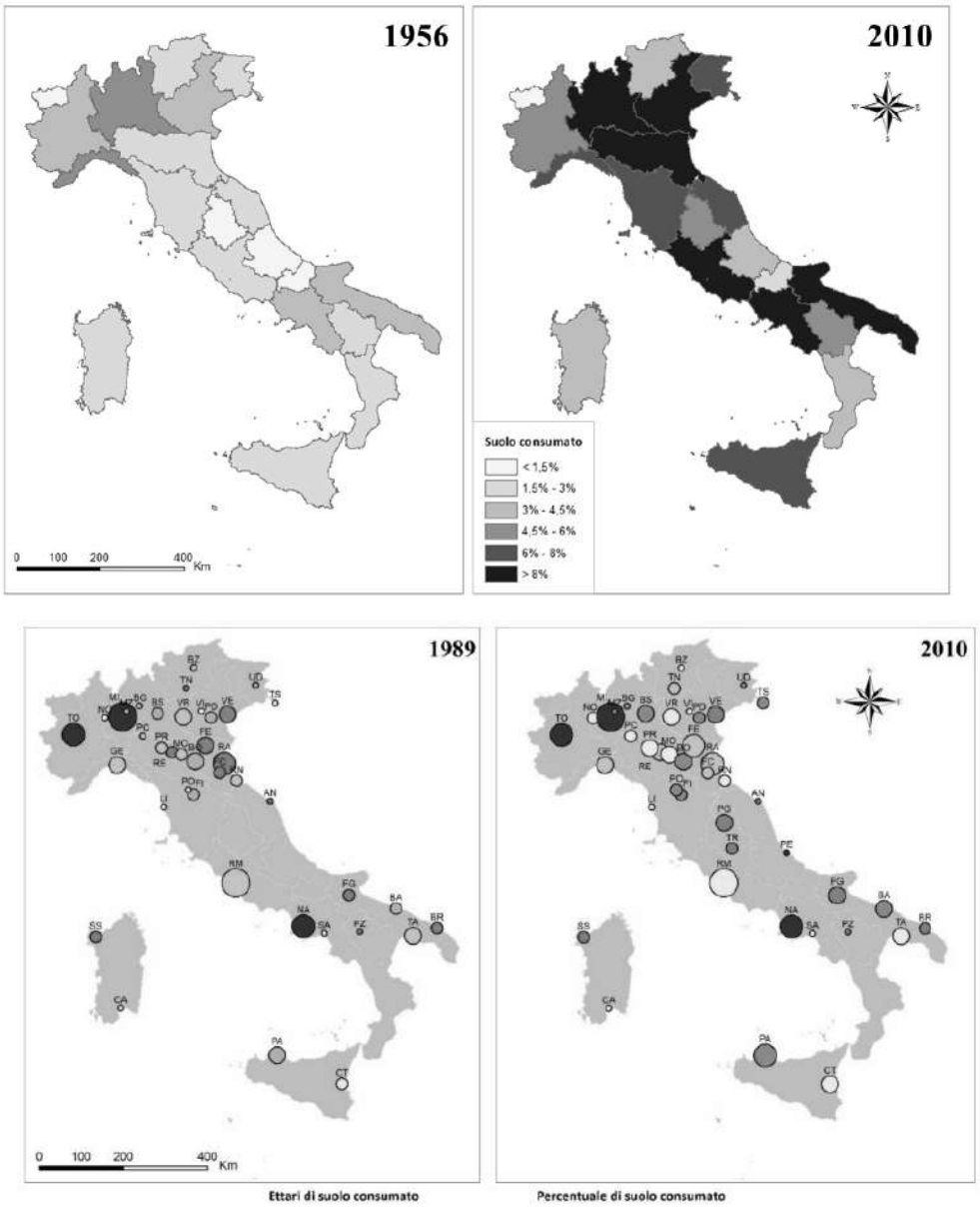


Figure 3.23. Urban area (%) by administrative region (top) and soil consumption in the main Italian municipalities (bottom).

Comparing time series data (Table 3.13) illustrates the direction of the major changes in land-use at the national level. Cultivated areas moved from 58% of the total surface area in the 1960s to slightly more than 50% in 2006, pastures and grassland from 19% to 10%. In the same period, artificial areas have moved from 1% to almost 5% at the national level, while the increase in the wooded area was even greater, from 19% to 30%.

Table 3.13. Percent distribution of land-use in Italy in 1960, 1990, 2000 and 2006.

Land-use	1960	1990	2000	2006
Agricultural areas	37.89	28.44	29.31	29.10
Heterogeneous agricultural areas	10.44	16.09	13.65	13.96
Arboreal cultivations	9.79	7.33	7.50	7.68
Total cultivated areas	58.12	51.86	50.46	50.74

Woodlands	18.70	30.58	32.54	29.67
Pastures and semi-natural open areas	18.72	10.09	9.23	10.09
Artificial areas	1.34	3.98	4.55	4.97
Water, rock, unproductive areas	3.12	3.49	3.22	4.53

Source: data processing Falcucci and Majorano (2008), EEA (2010) and ISPRA (2011).

In urban areas, land consumed has begun from 64.7% in 1990 to 67.6% in 2006. By comparing the data based on a Corine Land Cover (CLC) map, the increase in soil consumption affects continuous urban fabric (82.4% in 1990, 84.8% in 2006), discontinuous urban fabric (61% in 1990, 64.1% in 2006), mining areas, landfills and courtyards (51% in 1990, 58.3% in 2006 (Table 3.14). As regard sports and recreation areas, if the consumed area was 23.8% in 1990, it exceeded 27% in 2006, highlighting intense construction and renovation sports facilities and related infrastructures.

Table 3.14. Intensity of land consumption by urban uses in CLC (third-level) classes.

Code	Type of land-use	Land consumed (%)		
		1990	2000	2006
111	Continuous urban fabric	82.4	83.2	84.8
112	Discontinuous urban fabric	61.0	61.9	64.1
121	Industrial or commercial areas	70.6	72.0	73.6
122	Road and railway networks and accessory spaces	66.0	65.4	69.4
123	Port areas	85.3	86.3	86.2
124	Airports	29.9	30.5	37.2
131+132+133	Mining areas, landfills and yards	51.0	53.2	58.3
141	Urban green areas	31.4	32.6	30.2
142	Sports and Recreation Areas	23.8	24.3	27.6

The increase of artificial areas in Italy confirms an uneven distribution among the different regions (Table 3.15). More than 60% of the transformations between 1990 and 2006 are concentrated in six regions: Piedmont, Lombardy, Veneto, Emilia Romagna, Tuscany and Sardinia. If the annual growth rate remains almost constant between 1990 and 2006, amounting to around 8000 ha per year, there are regions (such as Lombardy) which go from a rate of 500 ha per year between 1990 and 2000 to 1000 ha per year between 2000 and 2006. Veneto region has a similar trend (from 600 to 1300 ha per year). In Sardinia, on the contrary, the annual urbanization rate varies from 1200 ha per year between 1990 and 2000 to less than 300 ha (2000-2006). The Ambiente Italia 2011 report by Legambiente and the National Urban Planning Institute estimates that urban growth is even higher, stabilizing to about 10000 ha of land per year (Bianchi e Zanchini 2011).

Table 3.15. Variation of artificial areas by administrative region in Italy, 1990-2006.

Region	1990 - 2000		2000 - 2006		1990 - 2006	
	[ha]	[ha/year]	[ha]	[ha/ year]	[ha]	[ha/ year]
Piedmont	9015	902	3826	638	12841	803
Valle d'Aosta	961	96	-	-	961	60
Lombardy	5431	543	6252	1042	11683	730
Trentino-Alto Adige	1910	191	185	31	2095	131
Veneto	6232	623	7872	1312	14104	882
Friuli-Venezia Giulia	3783	378	1185	198	4968	311
Liguria	80	8	167	28	247	15
Emilia-Romagna	10456	1046	5337	890	15793	987
Tuscany	8137	814	4061	677	12198	762
Umbria	1377	138	681	114	2058	129
Marche	532	53	1978	330	2510	157
Latium	4213	421	3577	596	7790	487

Abruzzi	3591	359	921	154	4512	282
Molise	314	31	387	65	701	44
Campania	3058	306	1965	328	5023	314
Apulia	1141	114	3394	566	4535	283
Basilicata	1982	198	758	126	2740	171
Calabria	6116	612	2285	381	8401	525
Sicily	2345	235	1746	291	4091	256
Sardinia	11671	1167	1638	273	13309	832
Italy	82346	8235	48216	8036	130562	8160

Note: Estimates are based on Corine Land Cover data and, for this reason, figures do not consider land-based transformations less than five ha. Source: data processing ISPRA (2011).

3.6.2. Metropolitan encroachment and demographic growth

Soil consumption is only partly related to demographic growth in Italy. While trends in resident population in Italy have stabilized since the 1980s, soil sealing was growing at a high and almost constant growth rate over time. This phenomenon cannot be explained with the potential growth of housing demand and the related, latent level of urbanization.

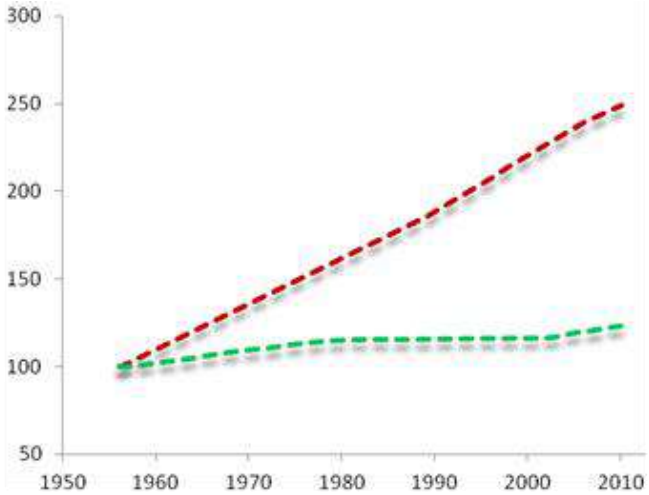


Figure 3.24. Land consumption (red line) and population residing in Italy (green line) between 1956 and 2010. Plot A was obtained by normalizing data to 100.

If, in 1956, 170 m² per capita were urbanized, in 2010 this value doubled to more than 340 m². Another significant indicator was the intensity of land-use expressing the relationship between the number of inhabitants and the hectares of land consumed. The values of this indicator gradually decreased between 1956 (59 inhabitants/ha) and 2010 (29 inhabitants/ha) since, as mentioned above, the rate of urban growth consumed exceeded that of the population, mainly boosted by the uneven expansion of peri-urban areas.

Table 3.16. Estimation of per capita soil consumption and intensity of land-use.

Year	Per-capita sealed land (m²)	Intensity of land-use (inhabitants/ha)
1956	170	59
1989	272	37
1996	303	33
1998	313	32
2006	339	30
2010	343	29

Source: ISPRA (2011)

The sealing surface has now exceeded 6% in Italy (Table 3.17). The highest values are found in Northern Italy, while Southern regions and Islands have shown slightly lower percentages (ISPRA, 2011). The diachronic data analysis proved a gradual increase in soil sealing in Italy from the mid-1950s.

Table 3.17. Soil sealing in Italy by geographical area (1956-2006).

Geographical area	Soil sealing (%)			
	1956	1994	1999	2006
North-western Italy	3.19	6.42	6.72	7.33
North-eastern Italy	2.55	5.59	6.08	6.68
Central Italy	2.20	5.22	5.26	6.25
Southern Italy	2.04	4.79	4.86	6.00
Islands	1.91	4.44	4.55	5.37
Italy as a whole	2.38	5.30	5.50	6.34

Source: ISPRA (2011)

If the Northern district has assumed the highest percentage of sealing surface, Southern Italy has recorded the largest increases since 1956. The degree of sealing of the national territory, equal to 2.4% in 1956, thus stand at 6.3% in 2006. The first period (1956-1994) was linked to massive post-war urban growth. The following period (1994-2006), however, was characterized by widespread urban development, typical of coastal and flat peripheral areas, with a growing trend since 2000. During this period, sealing was no longer related to population growth, with a net effect on the perceived land consumption significantly higher than that of compact and high-density urban growth typical of the first decades after World War II, accompanied by a parallel demographic development. In the main urban areas, soil sealing now extends, in some cases, to more than half of the municipal territory (more than 60% in the municipalities of Milan and Naples), with a growing trend seen in the municipality of Rome, an increase in the sealing surface of more than 300 ha yr-1 in recent years (Munafò et al., 2010).

According to statistical data provided by Italian National Statistical Institute (Istat) over the decade 1995-2006, nearly 50,000 new residential buildings and 200,000 dwellings were built per year, totaling a volume over one billion of new cubic meters (Berdini, 2010). These volumes were totally decoupled from the residential needs of the Italian population. The latter began to grow slowly (and mainly due to the contribution of immigrants) since 2000. In the same period, nearly 250 million m^2 of new buildings have been completed mainly for commercial or productive activities.

However, data evidenced a high rate of soil consumption in almost all major Italian municipalities and a continuous increase in sealed surfaces, caused by urban expansion and new infrastructures, with a general acceleration in the years following 2000. The comparison with the resident population allows to analyze the relationship between potential housing demand and soil consumption, strongly motivated by urban dispersion, which leads to a decrease in average sealing (Table 3.18).

The intensity of use, that is the ratio between the number of inhabitants and the sealing surface, represents an effective indicator for assessing settlement type. Higher values of intensity of use are related to urban contexts showing a greater compactness (e.g., Genoa, Naples and Turin) while, on the contrary, reduced values are typical of the low-density cities, where the ratio between the number of inhabitants and the sealed surface is lower (for example Ferrara, Ravenna and Potenza). A significant reduction in the intensity of use appears in Rome, ranging from 110 inhabitants per

hectare of 1990 and 80 in 2008. These values are well represented by the progressive trend towards urban dispersion in the capital city. Data confirm that soil consumption in the main Italian cities is a worrying phenomenon, which, particularly at the margins of urban areas, leads to the fragmentation of semi-natural landscapes.

Table 3.18. Sealing surface per capita and intensity of use in selected Italian cities (1990-2008).

	Sealing surface per capita [m²/hab.]					Intensity of use [hab./ha]				
	1990	1994	1998 1999	2004 2007	2008	1990	1994	1998 1999	2004 2007	2008
Ancona	-	155	157	166	-	-	64.4	63.7	60.3	-
Bari	-	122	126	134	-	-	82.0	79.2	74.6	-
Bergamo	-	143	145	-	154	-	70.0	68.9	-	64.7
Bologna	-	121	124	137	-	-	82.5	80.7	72.8	-
Bolzano	-	118	122	121	120	-	84.7	81.7	82.5	83.1
Brescia	-	197	202	210	-	-	50.7	49.5	47.7	-
Cagliari	-	117	123	136	-	-	85.3	81.3	73.3	-
Catania	-	119	124	145	-	-	84.3	80.8	69.1	-
Ferrara	-	417	431	454	-	-	24.0	23.2	22.0	-
Florence	-	87	92	102	-	-	115.4	109.1	98.4	-
Foggia	-	203	217	245	-	-	49.1	46.1	40.8	-
Forli	-	273	283	309	318	-	36.6	35.3	32.4	31.5
Genoa	-	68	73	74	-	-	146.1	137.8	134.7	-
Livorno	-	130	135	141	-	-	77.1	74.2	70.7	-
Milan	-	81	84	86	-	-	124.2	119.0	116.7	-
Modena	-	197	201	221	-	-	50.9	49.7	45.3	-
Monza	-	123	125	129	-	-	81.4	79.9	77.8	-
Naples	-	69	71	75	-	-	144.5	140.8	133.9	-
Padua	-	171	175	182	-	-	58.4	57.1	54.8	-
Palermo	-	84	85	90	-	-	118.7	117.9	110.8	-
Parma	-	243	252	282	-	-	41.1	39.6	35.4	-
Perugia	-	-	-	347	343	-	-	-	28.8	29.1
Piacenza	-	201	211	253	-	-	49.8	47.3	39.6	-
Potenza	-	307	305	330	-	-	32.6	32.8	30.3	-
Prato	-	151	150	156	-	-	66.3	66.5	64.2	-
R. Emilia	-	269	266	252	-	-	37.2	37.6	39.7	-
Ravenna	-	546	571	580	-	-	18.3	17.5	17.2	-
Rimini	-	216	219	222	-	-	46.4	45.6	45.0	-
Rome	91	108	117	129	125	109.5	92.5	85.5	77.6	80.0
Salerno	-	103	106	125	-	-	97.2	94.5	80.1	-
Taranto	-	204	218	248	-	-	49.0	45.9	40.3	-
Turin	-	75	80	79	-	-	132.7	124.4	127.3	-
Trieste	-	114	121	136	-	-	87.7	82.5	73.8	-
Udine	-	216	223	228	-	-	46.3	44.9	43.9	-
Venice	-	164	171	200	-	-	61.0	58.3	50.1	-
Verona	-	190	198	203	-	-	52.6	50.4	49.3	-
Vicenza	-	189	191	187	-	-	53.0	52.5	53.3	-
Italy	-	281	291	323	-	-	35.6	34.4	30.9	-

Source: Munafò et al., (2011a).

3.6.3. Empirical suggestion from Italy

Multi-temporal and spatial analysis of the dynamics of soil consumption in Italy allows identifying relevant factors that guide urban dispersion processes (Munafò et al., 2003). Changes in

territorial distribution of settlements are explained by considering a relatively long period of time in this study. Results from the period 1950s- 1970s have reflected economic recovery and urbanization processes that followed World War II (Munafò et al., 2013). Subsequently, there was a progressive decoupling of these factors. Among the main drivers of soil consumption, from the 1980s urban sprawl and the expansion of tourism activities (especially along the coastal strip) started to emerge. They were also enhanced by illegal and informal settlements, economic or financial speculation and the builders' rights. In this second timeframe, soil consumption did not reflect the real housing, social and economic needs of the population (Rontos et al., 2016).

The shifted spatial distribution of soil sealing also reflected specific land-use trajectories such as sprawl, decentralization, agricultural intensification and land abandonment. The latter mainly affected Mediterranean coastal areas and the Po Valley. Due to semi-arid climatic conditions, presence of soils with a strong tendency to erosion or salinisation, exploitation of water resources, the impact of these processes on soil quality is worrying. It had a negative impact on Italian sustainable development, especially in less resilient areas where the links between biodiversity, landscape, social factors and economic activity are stronger (UNCCD 1994, Simeonakis et al., 2007; Sirami et al., 2010; Salvati et al., 2013b).

With the intention of turning around the trend towards cementation, saturation and destruction of Italian territory, a multidisciplinary approach is needed. Approaches and methodologies should be based on general and shared reference points at European level to achieve the objective of "drawing the future", which is just about every form of territorial planning and management. In this regard, the importance of providing new guidelines was underlined in the document produced by the European Commission on Soil Empathy (Guidelines on Good Practices to Restrict, Mitigate and Compensate Waterproofing) in 2012. They considered soil quality as a fundamental prerequisite for territorial planning, with the purpose of preserving its existing capabilities and value. The approach followed the principles of (i) limitation, (ii) mitigation and (iii) compensation.

Limiting soil sealing means to put off, totally or partially, the conversion of green areas and the resulting sealing of their surface layer. This includes the reuse of already built-up areas, orienting new settlements towards low quality soils, evaluated according to the functions offered by a given area and the impact of sealing on these functions (Mavrakis et al., 2015). When soil loss is inevitable, mitigation measures should be taken in the context of land management and planning processes, aiming at maintaining some of the soil functions and alleviating the significant negative impacts on the environment and living organisms. Such measures include the use of permeable materials instead of cement or asphalt, supporting "green infrastructure" and increasing the use of natural systems for water collection (Barbati et al., 2013; Cimini et al., 2013; Marchetti et al., 2014).

In the case measures of limitation and mitigation are insufficient, compensatory measures can be applied. The objective is to support or restore the wide-ranging soil capacity in degraded areas. So, they can - at least partly - perform their functions, reusing for example the removed ground land for preparing a building or a road, or restoring part of the previous soil, by the removal of waterproofed layers such as asphalt or concrete. By completing and updating databases on soil consumption, useful information can raise public awareness of the environmental consequences of extra-urban development and soil sealing (Munafò et al., 2013). The results produced and the possibility of a continuous update on the state of the investigated phenomenon can help to stimulate

the containment of uncontrolled and unplanned urban expansion (Salvati and Ferrara, 2013), which is possible through urban regeneration, the recovery of historic centers and more compact and semi-dense settlement forms.

The containment of soil consumption is a widely shared goal in many of the new regional land legislation in Italy (Arcidiacono, 2009). However, data demonstrated the relevant difficulty of realizing and implementing effective policies and practical tools. The process of transforming agricultural and natural soil into urban and artificial uses continues unceasingly over time, fragmenting large territories, often with a high environmental, agronomic and landscape value (Salvati and Ferrara, 2014). The systematic analysis of how much soil is consumed, combined with the evaluation of the quality and uses that the soil itself had before being transformed, is an indispensable element to support decisions in the sphere of land policy (Serra et al., 2014, Tombolini and Salvati, 2014b, Zitti et al., 2015; Zambon et al., 2017a). A wide-ranging analysis of urban development trends can suggest to policy-makers useful measures to plan urban expansion and land-use (Carlucci et al., 2017). The obtained findings stimulate to reflect on the importance of supporting or restoring soil capacity, especially in degraded areas. At local level, joint analysis of aerial photographs and satellite imagery combined with field surveys, interviews with privileged stakeholders and bibliographic/cadastral archives allows for detailed analysis, including for setting up environmental plans and territorial programs. Regional planning instruments are the tools by which to ensure the containment of soil consumption and the compatibility of development choices with the preservation and improvement of environmental and social quality. However, there is a national law that limits, or at least controls, soil consumption, being inspired to similar experiences in other European countries. In this direction, local administrations, with a few exceptions, do not feel the need to change direction or recognize the responsibility for the effects of their choices on the collective heritage of the environment, soil, and landscape and cultural heritage. Participation of local master plans in a broader program for urban containment is particularly needed in economically-dynamic districts devoted to continuous urban growth in the coming future.

3.7. Exploring the spatial mismatch between planned and actual land-use

Industrial development and related socioeconomic transformations have influenced the structural identity of cities since the 18th century, promoting multiple ways of urban expansion - from radio-centric growth to 'leapfrogging' and 'strip' development along road networks. As a result of infrastructural development and enhanced place accessibility, urbanization rates have risen considerably since the end of the 19th century in both affluent and emerging countries (Antrop 2004). Population living in urban areas increased significantly with negative effects on life quality and environmental sustainability (Nowak and Walton 2005).

As urban areas have been physically divided from the surrounding rural land for a long part of their history, urbanization in Europe has led to a clear distinction between historical and modern cities. A comprehensive analysis of urbanization processes in the last century has evidenced changes in metropolitan structures, and the related socioeconomic characters, in many European cities (Brenner 2003; Soja 2011; Mariano 2014). Experiencing new types of regional development, structurally-heterogeneous and spatially-differentiated urban models were observed, spanning from semi-dense to dispersed metropolitan growth (Champion 2001). Changes in lifestyles, improved economic conditions and increased private mobility were at the base of more recent suburbanization processes (Rontos et al., 2016; Duvernoy et al., 2018; Zambon et al., 2018), making discontinuous settlements particularly attractive for specific population segments and social classes (Burchell et al., 2000; Ewing et al., 2002; Tombolini et al., 2015). These transformations have shaped new multifunctional landscapes undergoing socioeconomic, political and cultural change (Hodge 2001; Antrop 2004; Conacher 2009).

Cited article

Clemente, M., Zambon, I., Konaxis, I., Salvati, L. (2018). Urban Growth, Economic Structures And Demographic Dynamics: Exploring The Spatial Mismatch Between Planned And Actual Land-Use In A Mediterranean City. International Planning Studies.

Recent transformations towards more heterogeneous urban forms and non-linear socioeconomic dynamics have involved several cities in Europe (e.g. Brenner 2003; Soja 2011; Mariano 2014), with globalization being considered one of the main drivers of change (Brenner and Theodore 2002; Brenner et al., 2010; Theodore and Peck 2011). In this framework, metropolitan regions turn out to become the engine of economic development and local competitiveness (Sassen 1991), shaping social and cultural hierarchies (Antrop 2005) and leading to fragmented economic structures, social disparities and heterogeneous peri-urban landscapes (Turok and Mykhnenko 2007; Serra et al., 2008; Salvati, 2014a).

In this regard, a discontinuous expansion of residential and service settlements has emerged as a persistent urbanization pattern (Seto 2010; Barrington-Leigh and Millard-Ball 2015; Abrantes et al., 2016). According to Gordon and Richardson (1997), discontinuous urban expansion reflects suburbanization in fringe districts. Socio-environmental impacts of discontinuous urbanization include loss of soil resources, inflated public spending and a declining social awareness (Barrington-Leigh et al., 2015; Storper 2016; Cuadrado-Ciuraneta et al., 2017). Although town planning has been considered an effective response to discontinuous urban expansion, the role of spatial planning in Europe has been quite emblematic in the last half century (Giannakourou 2005). Recent discourses on urban growth (e.g. Gordon and Richardson 1997; Porter 2000; Brenner and Theodore 2002) have

frequently hypothesized that spatial planning and the consequent regulatory constraints negatively affect local competitiveness, leading to forms of deregulated urban expansion.

Up to the late 1970s, spontaneous expansion was frequently observed in Mediterranean cities (Salvati 2013; Rontos et al., 2016; Cuadrado et al., 2017) with informal development sometimes prevailing on planned development, possibly thanks to a weak participation to land-use decisions, lack in institutional cooperation and a defective control against land appropriation and unauthorized buildings (Giannakourou 2005). Although new developments on unplanned land have historically represented a factor of urban fragmentation (Costa 1991; Krumholz 1992; Kourliouros 1997), laissez-faire practices have encouraged spatially-discontinuous developments in some cases (Carlucci et al., 2017), leading to a progressive shift from vertical city's growth towards a more dispersed (horizontal) expansion (Tombolini et al., 2015; Kazemzadeh-Zow et al., 2016; De Rosa and Salvati 2016).

Informal urban expansion was fueled by population growth, rural-urban migration, urban poverty, lack of social housing, services and infrastructures, inadequate planning regulations and administrative tools (Maloutas 2004; Arbaci 2007; Arbaci and Malheiros 2010; Di Feliciantonio and Salvati 2015). Overcoming planning and housing rights for speculative purposes, informal settlements have constituted a dominant form of urban growth in the 1960s' Athens or in the 1970s' Istanbul, being more frequently mixed with planned settlements in other large cities such as Barcelona, Salonika, Rome, Naples and Lisbon (Salvati and Gargiulo Morelli 2014; Carlucci et al., 2017). Delays and abuse in administrative procedures have been sometimes the result of (i) complex and opaque systems for releasing building permits, (ii) legal and technical frameworks with a low degree of applicability and (iii) frequent changes in the normative base, especially when local and regional policies failed to respond to rapidly changing socioeconomic contexts (Costa et al., 1991; Bengston et al., 2004; Giannakourou 2005).

While integrating town plans and open space preservation measures (Gennaio et al., 2009), urban management policies and land-use planning instruments require a more effective formulation of formal restrictions to settlement expansion beyond a definite spatial boundary, e.g. greenbelts or urban growth boundaries (Wassmer 2006; Aguilar and Santos 2011). For example, greenbelts have been demonstrated to contain (at least partially) the expansion of built-up areas into high-quality agricultural land (Bengston and Youn 2006). Spatial planning must adjust to transforming social, environmental and economic contexts, following multilevel and multi-actor policy making (Reimer et al., 2014). In this regard, land tenure reflects planning decisions and cultural, political, economic forces (Ligtenberg et al., 2004). With land market volumes being influenced by economic and social value of land, zoning rules may fix land-use rights and specific prescriptions regulating land transformation (Watson 2009). However, rules and guidelines specifically defined by town plans have been sometimes not respected or partly applied in Mediterranean contexts (e.g. Giannakourou 2005; Wassmer 2006; Salvati 2013).

In this regard, assessing the spatial mismatch between planned and actual land-use in Mediterranean cities is a relevant issue when investigating the latent relationship between urban transformations and spatial planning. However, lack of high-resolution digital land-use maps and geo-spatial databases derived from town planning made this deserving issue particularly intricate. In this line of thinking, the Rome's metropolitan area is a representative example of metropolitan

regions with both consolidated and scattered settlements resulting from a partial compliance with land zoning directives. Spatial distribution of settlements has been shaped by a socioeconomic background evolving rapidly in the last three decades (Costa et al., 1991; Archibugi 2004; Salvati and De Rosa 2014; Tombolini et al., 2015). While being characterized by different urban forms, other Mediterranean cities (e.g. Barcelona, Athens, Naples) have experienced similar transformations leading to social segregation and environmental degradation (Maloutas 2004; Arapoglou and Sayas 2009; Sargolini 2013; Di Feliciantonio and Salvati 2015; Di Rosa and Salvati 2016).

An integrated research framework based on the use of high-resolution digital maps of planned and actual land-use was adopted in this study with the aim to verify if deregulated urban expansion led to a progressive expansion of discontinuous settlements. Evaluating the contributing role of spatial planning to discontinuous urban expansion constitutes a knowledge base for effective land management strategies targeting soil conservation, urban containment and sustainable development of cities.

3.7.1. Spatial data and statistical analysis in Rome

94 out of 121 municipalities belonging to Rome's province were investigated (Figure 3.25). The selected municipalities constitute the Large Urban Zone (LUZ) of Rome defined by the European Urban Audit program, providing statistical data on a local and regional scale for several European cities. LUZs correspond to an area from which a significant share of the resident population commutes into the central city (Eurostat 2004); more than 20% of European population resides in a LUZ (Mubareka et al., 2011). This spatial domain was designed with the aim to analyze relevant data covering multiple research domains such as land-use, environment and transport.

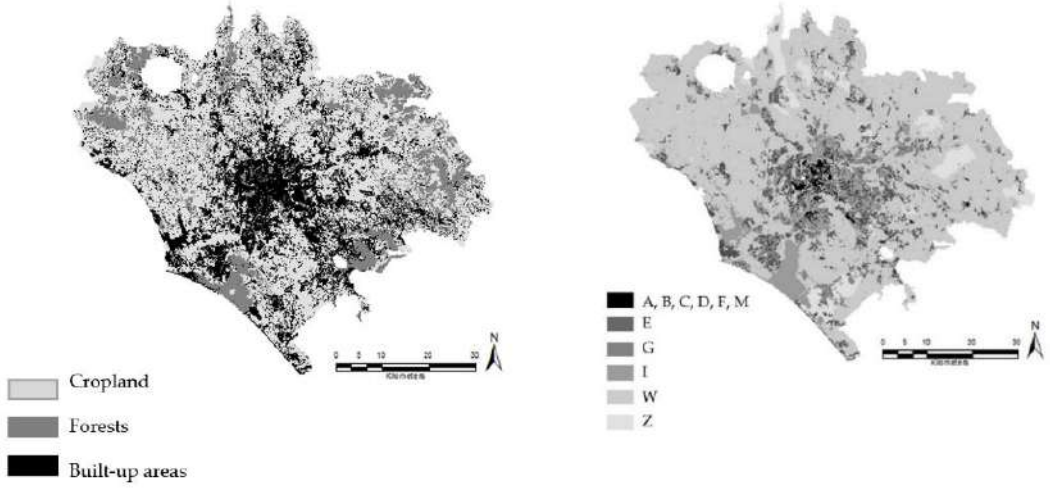


Figure 3.25. Maps representing actual land-use (lower-left panel) and planned land-use (lower-right panel).

Comparison of actual and planned land-use in the study area was implemented thanks to land-use maps derived from geospatial data sources made available recently and analyzed using a geographical information system. A map of actual land-use was derived from the Urban Atlas (UA) project, a European database carried out by the Land Copernicus initiative at Global Monitoring and Environmental Surveillance (GMES) program. UA allows identifying several land-use classes through standardized European-level codes distinguishing built-up areas from cropland and forests. In the UA legend (Table 3.19), all codes starting with '1' (from '11100' to '14200') identify

urban contexts, from dense and compact settlements to built-up areas devoted to services and recreational activities. Semi-natural and natural environments (including cropland, forests and water bodies) are identified respectively with codes '2', '3' and '5'.

A high-resolution map of planned land-use was also considered basing on land zoning approved by the most recent town plans in each municipality of the study area. This map was carried out and disseminated by the cartographical service of Rome's province and distinguishes land allocated to different classes through a specific nomenclature (Table 3.19): urban residential areas in central cities ('A'); self-contained residential urban expansion ('B'); newly built-up residential settlements ('C'); areas destined to services ('D'); agricultural and forest areas with building restrictions ('E'); land destined to equipment and systems of general interest ('F'); land under partial building constraints ('G'); wetlands and other areas surrounding water bodies ('I'); transport infrastructures ('M'); out-of-plan land ('W'); and unclassified, mixed urban-rural areas, with mainly non-urban land destination ('Z').

Table 3.19. Land-use nomenclature and codes used in this study.

Code	Class
	Urban Atlas land-use nomenclature
1110	Continuous Urban Fabric (S.L. > 80%)
1121	Discontinuous Dense Urban Fabric (S.L.: 50% - 80%)
1122	Discontinuous Medium Density Urban Fabric (S.L.: 30% - 50%)
1123	Discontinuous Low-Density Urban Fabric (S.L.: 10% - 30%)
1124	Discontinuous Very Low-Density Urban Fabric (S.L. < 10%)
1130	Isolated Structures
1210	Industrial, commercial, public, military and private units
1221	Fast transit roads and associated land
1222	Other roads and associated land
1223	Railways and associated land
1230	Port areas
1240	Airports
1310	Mineral extraction and dump sites
1330	Construction sites
1340	Land without current use
1410	Green urban areas
1420	Sports and leisure facilities
2000	Agricultural, (non-forest) semi-natural areas, Wetlands
3000	Forests
5000	Water bodies
	Land zoning derived from town master plans
A	Residential urban areas in city centers
B	Self-contained urban residential expansion
C	Newly built-up residential settlements
D	Areas destined to services
E	Agricultural and forest areas with building restriction
F	Land destined to equipments and systems of general interest
G	Land under partial building constraints
I	Wetlands and other areas surrounding water bodies
M	Transport infrastructures
W	Out-of-plan areas
Z	Unclassified, mixed urban-rural areas, mainly non-urban

This classification was derived from a preliminary analysis of town plans and provides an implicit standardization in few categories relevant to the scope of exploratory study. Despite spatial variability in town plan regulations and land zoning systems, geo-referenced data derived from town plans have generated reliable indicators for statistical analysis, allowing an appropriate comparison with Urban Atlas land-use nomenclature. Agricultural and forest areas in the UA map (classes '2' and '3') were classified in a coherent zoning class (class "E"), including land with specific rural characters (forests, non-forest natural areas and high-quality, mixed cropland), together with public and private green areas under specific measures of landscape and environmental conservation (e.g. hydro-geological constraints to building). The "F" class includes small green areas providing well-equipped facilities, e.g. sports facilities, together with parking areas, school services, open markets and hospital services. A spatial mismatch in planned and actual land-use was detected (i) when the surface area of urban fabric in total agricultural or (public/private) green areas was higher than 10%; or (ii) when actual land-use was different from land destination reported in the zoning map. Data collection and editing were carried out using ESRI ArcMap 10 software.

A Principal Component Analysis (PCA) was run on a data matrix composed of percent surface area of each land-use class in total municipal area derived from a spatial intersect of the two maps illustrated above. By exploring the land-use regime typical of the Rome's metropolitan area, the PCA classified actual and planned land-use classes into homogeneous groups according to their spatial distribution in the study area. Components with eigenvalue > 2 and loadings > |0.5| were considered in the analysis (Salvati 2013). Non-parametric Spearman rank coefficients were used to correlate pair-wise (i) selected socioeconomic attributes profiling each municipality of the study area with (ii) a set of mismatch indicators assessing percent surface land classified as one of the (actual land-use) UA codes '1.x' (identifying built-up areas) in the total surface area of land classified as one of the planned land-use (namely 'E', 'F', 'G', 'W' or 'Z' classes). Significant correlations were tested at $p < 0.05$ after Bonferroni's correction for multiple comparisons.

3.7.2. Urban expansion, zoning and the socioeconomic local context

The percent share of built-up areas (corresponding to codes '1.x' of the Urban Atlas nomenclature) in the total surface area by land destination class (corresponding to classes from 'E' to 'Z' of the standardized land zoning nomenclature), was calculated at the municipal scale (Table 3.20). Urban settlements expanded into agricultural land ("E" class) in municipalities close to Rome - particularly along the southern boundaries of the city. Suburban municipalities (such as Ciampino and Nemi) showed the highest figures (more than 50%) for this indicator. The percent surface of built-up areas in total area of "W" and "Z" land classes (indicating out-of-plan land or a mixed/poorly defined land destination) was higher than 20% in 25 municipalities with medium-high urbanization pressure. The highest values of this indicator were observed in Anzio (100%), Nemi (83%) and Colonna (69%), three municipalities experiencing intense suburbanization in recent times. High values of the same indicator referring to the "Z" zoning class were found in several municipalities of the study area. Inner Rome had a relatively high share of built-up areas in both "W" (41.4%) and "Z" (67.8%) areas.

Table 3.20. Percent share of built-up areas (pooling together land classified with Urban Atlas codes '1.x') in total class area (from 'E' to 'Z') by land destination; 'na' indicates absence of the respective class at the municipal level.

Municipality	E	F	I	W	Z	Municipality	E	F	I	W	Z
Affile	0.0	na	na	1.4	na	Marcellina	6.6	32.2	na	4.1	7.7
Albano Laziale	29.7	51.8	na	36.4	100.0	Marino	38.2	56.7	3.8	26.5	na
Anguillara Sabazia	11.5	15.3	19.6	3.9	49.3	Mazzano Romano	25.6	23.3	3.6	na	5.4
Anticoli Corrado	0.0	na	na	0.0	na	Mentana	16.3	7.7	na	2.7	na
Anzio	na	na	na	100.0	na	Monte Porzio Catone	15.9	30.4	na	11.6	na
Ardea	19.1	36.5	na	14.9	96.6	Montecompatri	17.9	51.8	na	21.2	33.7
Ariccia	36.3	37.6	na	46.6	69.7	Monteflavio	3.9	0.1	na	8.9	na
Artena	2.4	na	na	1.2	na	Montelibretti	4.5	68.7	1.3	na	0.0
Bellegra	6.2	38.9	na	1.4	na	Monterotondo	7.7	41.8	2.5	14.4	na
Bracciano	6.1	27.7	12.3	4.0	na	Moricone	6.3	na	na	5.7	na
Campagnano di Roma	20.1	39.9	na	1.1	18.3	Morlupo	9.7	19.8	na	10.2	7.5
Canale Monterano	7.7	45.0	1.1	4.4	na	Nazzano	7.4	na	na	0.6	na
Canterano	0.0	na	na	0.0	na	Nemi	63.8	68.4	0.0	83.1	na
Capena	11.3	46.9	4.0	25.9	93.7	Olevano Romano	11.9	45.7	16.3	6.4	11.5
Capranica Prenestina	1.0	23.1	na	0.1	na	Palestrina	25.8	64.2	na	16.5	56.1
Casape	1.4	23.4	1.9	1.3	1.5	Palombara Sabina	10.7	70.9	na	2.3	na
Castel Gandolfo	35.2	39.2	8.9	34.4	63.4	Percile	0.0	na	0.0	0.0	0.5
Castel Madama	9.8	29.5	na	0.8	26.8	Pisoniano	1.9	30.9	na	0.2	na
Castel San Pietro	4.0	36.0	na	8.8	na	Poli	4.0	13.3	na	3.1	67.1
Castelnuovo di Porto	25.0	41.9	na	19.4	8.2	Pomezia	na	53.1	na	35.8	15.7
Cave	24.1	51.8	na	7.8	19.7	Riano	12.7	41.6	na	29.9	na
Cerreto Laziale	2.1	23.8	na	26.3	94.9	Rignano Flaminio	9.3	40.2	na	10.8	20.5
Cerveteri	9.4	37.5	na	2.2	42.7	Rocca Canterano	0.0	na	na	na	na
Ciampino	52.7	61.7	na	46.5	31.8	Rocca di Cave	3.6	49.1	na	8.0	na
Ciciliano	2.1	6.7	0.1	0.0	0.4	Rocca di Papa	26.4	8.2	na	26.6	61.6
Civitella San Paolo	7.3	19.5	0.0	28.4	7.7	Rocca Priora	34.3	8.2	na	14.3	73.1
Colleferro	na	na	0.0	0.0	0.0	Rocca Santo Stefano	0.0	na	na	2.2	na
Colonna	18.8	45.3	na	69.0	na	Roiate	1.1	na	na	1.2	na
Fiano Romano	18.4	23.4	4.6	11.9	93.4	Roccagiovine	na	na	na	na	0.4
Fiumicino	5.8	53.3	4.7	8.8	34.4	Roma	12.5	28.0	6.8	41.4	67.8
Fonte Nuova	28.4	13.5	na	48.5	37.9	Sacrofano	19.1	7.2	4.6	0.7	40.5
Formello	na	9.5	na	14.6	18.0	Sambuci	2.3	56.0	13.7	3.0	0.0
Frascati	22.7	57.9	na	30.1	49.8	San Cesareo	39.0	53.5	na	33.9	10.0
Gallicano_nel_Lazio	19.7	24.7	na	1.0	na	San Gregorio da Sass.	na	29.3	na	na	2.9
Genazzano	11.5	41.8	34.1	1.1	na	San Polo dei Cavalieri	0.9	43.8	na	2.5	29.6
Genzano di Roma	23.7	55.2	na	42.8	79.0	San Vito Romano	3.5	42.2	0.0	3.9	16.7
Gerano	6.1	49.3	na	0.0	18.1	Sant'Angelo Romano	12.8	20.6	na	11.3	na
Grottaferrata	26.0	38.6	na	41.6	74.6	Santa Marinella	na	na	na	na	6.6
Guidonia Montecelio	17.1	61.4	na	28.8	62.7	Sant'Oreste	2.0	32.6	0.0	24.4	4.0
Labico	13.1	na	na	3.6	na	Saracinesco	1.7	11.2	na	1.8	2.9
Ladispoli	21.0	31.8	14.6	35.5	3.7	Tivoli	12.6	22.8	15.9	17.1	9.2
Lanuvio	23.5	na	na	31.7	na	Tolfa	22.8	na	na	0.4	0.0
Lariano	0.0	na	na	0.0	na	Trevignano Romano	8.7	45.7	3.4	4.9	89.4
Licenza	1.8	63.4	7.2	0.1	na	Valmontone	14.4	na	na	29.6	na
Magliano Romano	3.2	75.3	na	0.0	28.7	Velletri	14.5	na	na	19.9	na
Mandela	na	na	na	na	0.0	Vicovaro	1.8	24.3	3.3	1.1	2.0
Manziana	10.6	44.9	na	8.4	na	Zagarolo	36.1	48.9	na	32.7	na

By investigating multiple relationships between planned and actual land-use, results from the analysis of component loadings indicate a latent urban gradient in Rome. Principal Component (PC) 1 accounts for 24.6% of the total variance and outlines a spatial association between natural areas

and out-of-plan land, contrasting with the spatial distribution of residential settlements in consolidated cities. PC2 (18.2%) indicates a spatial divergence between self-contained residential settlements and urban land destined to services. PC3 (14.7%) is associated with natural areas including wetlands and water bodies. Finally, PC4 (11.6%) outlines a spatial divergence between industrial/commercial settlements and unclassified, mixed urban-rural (mainly non-urban) land. PCA biplot illustrates the joint distribution of planned and actual land-use, identifying processes of spatial convergence among land-use classes (Figure 3.26). The first two components characterized urbanization processes focusing especially on discontinuous expansion of residential settlements. The latter two components were associated with high-quality, protected natural land (wetlands, agricultural and forest areas). Discontinuous settlements expanded mainly into out-of-plan land or with mixed (or poorly defined) destination. These findings corroborate the hypothesis that discontinuous settlements expanded into rural land at a higher rate than continuous and compact settlements also thanks to lacking (or weak) regulatory constraints.

Table 3.21. Principal Component Analysis: loadings > |0.5| by planned land-use class.

Zoning	PC 1	PC 2	PC 3	PC 4
A	-0.65			
B	-0.62	0.63		
C			-0.55	
D				0.67
E	0.64		-0.62	
F		-0.79		
I	0.58		0.56	
M				
W	0.83			
Z				-0.70
Expl. Var. %	24.6	18.2	14.7	11.6

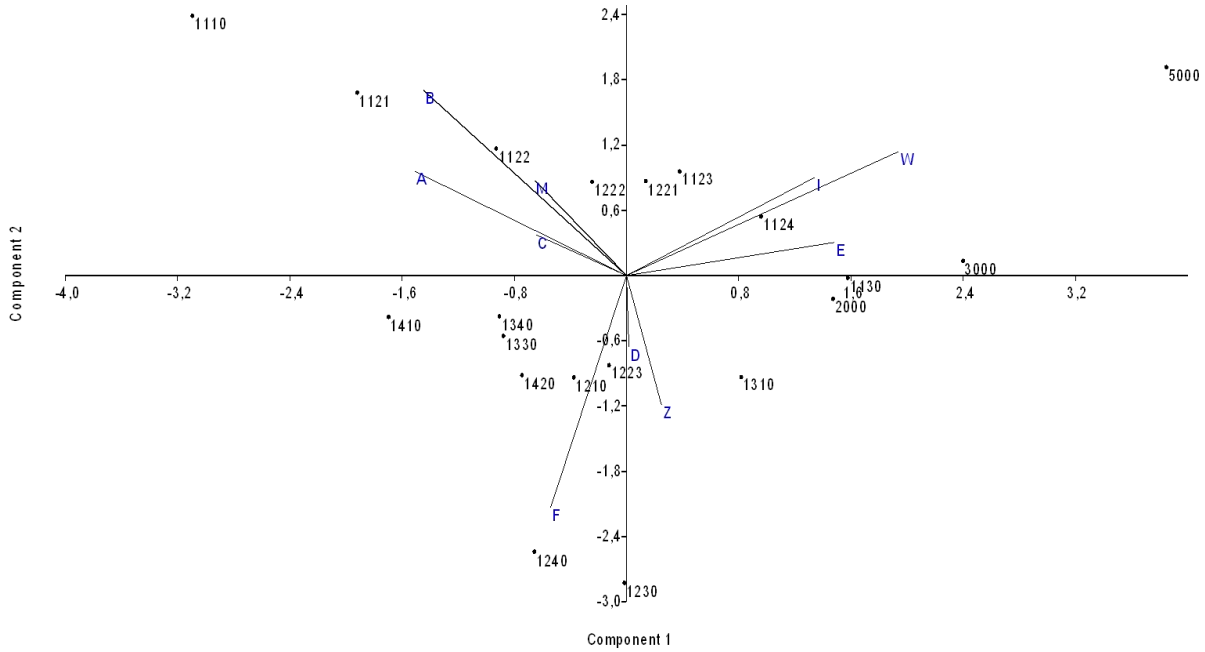


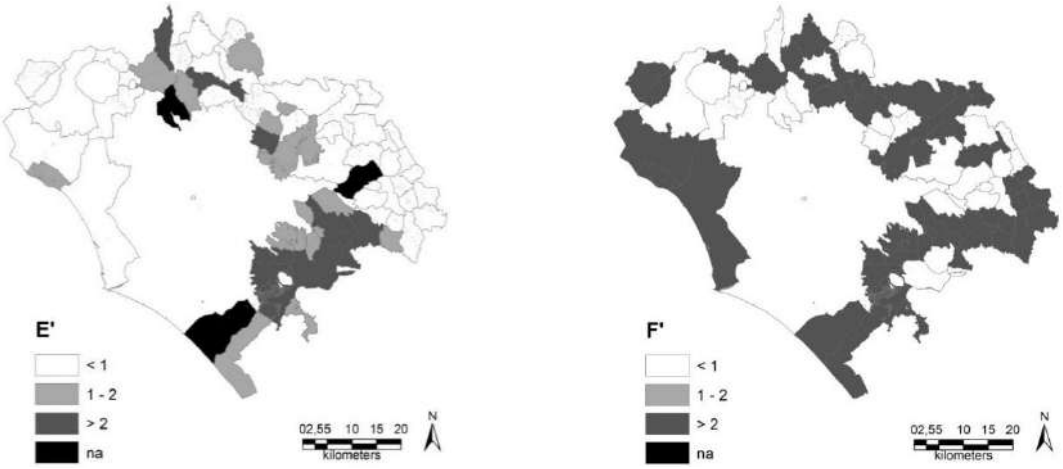
Figure 3.26. Principal Component Analysis biplot illustrating the spatial relationship between actual and planned land-use.

A Spearman rank correlation analysis was run between the percent share of built-up areas in total land area by zoning class and selected variables assessing the dominant socioeconomic conditions at the municipal scale (Table 3.22). A local context featuring high population density, a young demographic structure, a low density of foreign citizens, a moderately-low proportion of empty dwellings and a high number of rooms per dwelling was associated with settlements developed on land classified in the "E" zone. The prevailing economic profile of these municipalities reflects suburbanization processes with discontinuous settlements and a socio-demographic composition characterized by large families and wealthy households employed in business, commerce and credit sectors.

Table 3.22. Spearman rank correlation analysis between selected socioeconomic variables at municipal scale and the percent share of built-up areas (including '1.x' Urban Atlas codes) in the total class area (from 'E' to 'Z') by land destination; significance was tested at $p < 0.05$ after Bonferroni's correction for multiple comparisons.

Variable	E	F	I	W	Z
Population density	0.70			0.61	0.51
Average family size	0.60			0.47	0.43
Elderly index	-0.60			-0.44	-0.54
Share of foreign citizens in total resident population (%)	-0.61			-0.48	-0.48
Non-occupied dwellings in total dwellings (%)	-0.60				
Average number of rooms (residential dwellings)	0.47				
Employees in commerce sector (%)	0.47				
Employees in credit sector (%)	0.54			0.45	
Distance from downtown Rome	-0.65			-0.54	-0.43

Conversely, out-of-plan areas ("W") have attracted medium-low density settlements with prevalence of residents with upper working position mainly in the credit sector. Finally, the "Z" class (indicating unclassified and mainly non-urban areas) has attracted semi-dense settlements in suburbs and rural districts, being negatively correlated with elderly index and the share of non-native residents in total population.



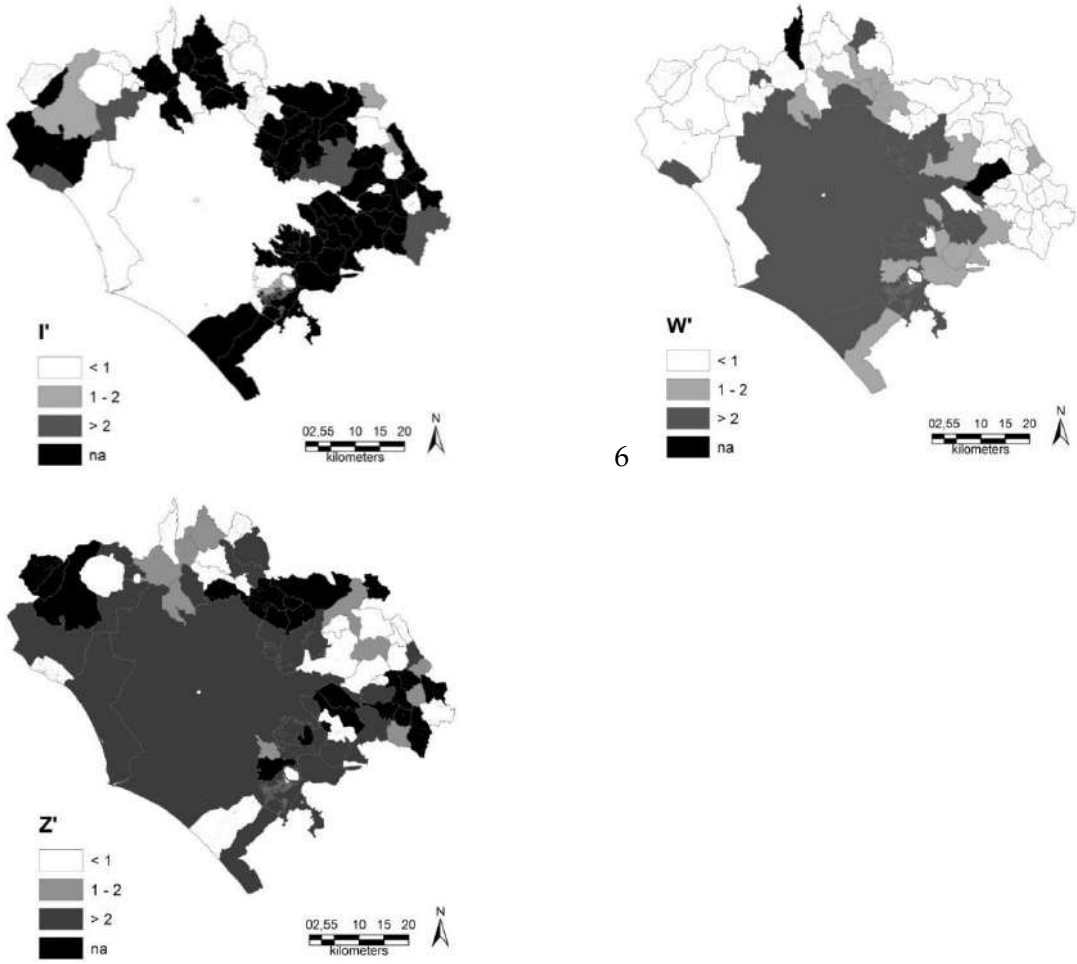


Figure 3.27. Percent share of built-up areas in total land area by selected zoning classes.

3.7.3. Toward economic competitiveness, social equity and environmental sustainability

Deregulated and informal urbanization in southern Europe was a relatively common pattern of growth in the aftermath of World War II (Insolera 1993; Giannakourou 2005; Salvati 2013; Serra et al., 2014; Zambon et al., 2017b). More recent urbanization processes have altered morphological structures and economic functions of European metropolitan regions expanding beyond their administrative boundaries (Brenner 2003; Brueckner 2007; Abrantes et al., 2016). With uneven cities' expansion and stable (or moderately declining) population, global and local social forces have significantly transformed Mediterranean peri-urban landscapes in the last decades (Antrop 2005). In this regard, spatial planning in Southern Europe has faced with rapidly evolving economic contexts, basing on operational tools more adapted to historical and consolidated urban areas and possibly less effective in containing the rapid expansion of suburbs under increasing speculative pressures (Allen 2003; Antrop 2004; Soja 2011; Mariano 2014).

The recent history of Rome's development is representative of a (partly deregulated) process of urban expansion under mixed socioeconomic forces. Comparing actual and planned land-use, this study has outlined a moderate spatial mismatch between land zoning and the current use of land along the urban gradient in Rome. While urban settlements have rarely expanded into strictly rural areas with formal restrictions to building, urbanization has more frequently involved out-of-plan land, with partial regulatory constraints or with mixed/heterogeneous land destination. These areas were often located in municipalities with growing population and rapidly increasing house demand,

resulting in high pressure for services and infrastructures. Low and medium density settlements - a typical outcome of discontinuous urbanization - have occasionally occupied agricultural land under building restrictions, expanding more rapidly into out-of-plan land. Based on these results, Rome's expansion has reflected a combination of planning decisions and informal practices leading to interrelated (and sometimes uncontrolled) urban transformations (Maloutas 2004; Arbaci 2007; Arbaci and Malheiros 2010; Zambon et al., 2017b). This evidence corroborates the results of earlier studies investigating spatial patterns of deregulated urban expansion in Rome as well as in other Mediterranean cities, such as Athens and Barcelona (Costa et al., 1991; Archibugi 2004; Giannakourou 2005; Chorianopoulos et al., 2010).

Following the empirical findings by Ewing et al., (2002), suburban contexts in Rome were characterized by a specific socioeconomic profile dominated by large families and residents employed in commerce and credit sectors (Zambon et al., 2017b), with housing preferences oriented to detached dwellings with gardens and swimming pools (Tombolini et al., 2015). Because of institutional fragmentation and heterogeneous economic actors, the empirical results of this study indicate that multi-dimensional approaches are particularly suited to identify urban dynamics and the underlying socioeconomic forces (Ricard 2005; Van Zanten et al., 2013; Salvati et al., 2015a).

Governing recent urbanization and the consequent landscape transformations needs appropriate planning solutions (Cakir et al., 2008; Terzi and Bolen 2009; Serra et al., 2014). Spatial planning is increasingly required to incorporate more effective measures for land conservation, targeting urban containment under more general strategies of sustainable metropolitan development (Zambon et al., 2015). In this perspective, earlier studies recognize the importance of a systematic evaluation of the effect of land management strategies in peri-urban contexts (Wassmer 2006; Gennaio et al., 2009; Colantoni et al., 2016).

While recent urbanization in Mediterranean Europe has been mostly oriented toward the European Spatial Development Perspective, policy measures promoting urban containment resulted to be effective only in few cases (e.g. Chorianopoulos et al., 2010; Colantoni et al., 2016; Zambon et al., 2018). Planning weaknesses have been related with endogenous and exogenous factors, including bureaucracy, administrative inertia, lack in field controls, complex operational and prescriptive rules and limited stakeholder's participation (Pastur et al., 2012; Tombolini et al., 2015; Duvernoy et al., 2018). According to the Ministerial Declaration on Social and Economic Changes in Distressed Urban Areas adopted by the UNECE Committee on Housing and Land Management in 2006 (ECE/HBP/2007/7, ECE/HBP/WP.7/2007/8), strategies containing urban growth and informal settlements are increasingly required to integrate town planning and social housing measures in a more coordinated policy system adopting principles of sustainable land management (Zitti et al., 2015).

In line with earlier studies (Gennaio et al., 2009; Zasada 2011; Abrantes et al., 2016), the empirical results obtained indicate that town planning can incorporate a sustainable land management strategies grounded on best practices including (i) urban regeneration and recovery of already urbanized areas, (ii) new developments in brown fields and low-quality non-urbanized land and (iii) continuous, semi-dense urban expansion consolidating suburban areas with discontinuous settlements (Wassmer 2006).

These measures are congruent with the European Union strategy aimed at containing urban expansion in a more general sustainable development framework. In this regard, the "Leipzig Charter on Sustainable European Cities" (EC 2007) has involved European stakeholders ensuring shared principles and strategies for national, regional and local urban growth policy. Moreover, aspiring to a more competitive knowledge-based economy, the "European Thematic Strategy on Urban Environment" (EC 2005) has stimulated the implementation of urban environmental policies at local level, supporting regional authorities in the adoption of a more integrated land management approach.

From the methodological point of view, considering (i) the high spatial variability in town planning regulations and (ii) the heterogeneous geo-spatial data, the empirical framework proposed in this study allows for an empirical analysis of land-use patterns (sensu Abrantes et al., 2016) with a focus on local trends (municipal scale) along an urban gradient from Rome to the surrounding rural areas. The study is eminently exploratory in its aims and adopts a statistical approach, providing general results that can be extrapolated to other contexts under specific research assumptions and socioeconomic conditions. A more detailed investigation of the intimate linkage between land zoning and land-use patterns requires a high-resolution, diachronic assessment of land-use change and a comprehensive analysis of the historical evolution of town and regional planning in each relevant administrative domain of the study area.

Adopting appropriate planning solutions for urban containments crucial for sustainable development of metropolitan regions (Zitti et al., 2015). Results highlights the increasing relevance of socioeconomic complexity and land fragmentation in metropolitan expansion, arising from spatially-heterogeneous patterns of growth and ineffective (or sub-optimal) land management and planning tools (Salvati and Gargiulo Morelli 2014). Going beyond a descriptive analysis of landscape structure and settlement morphology, empirical exercises comparing actual and planned land-use provide basic information contributing to inform policies aimed at controlling discontinuous urban expansion. In this regard, policy strategies are increasingly required to link spatial planning with multiple dimensions of local development, with the final objective to create (or re-create) conditions of economic competitiveness, social equity and environmental sustainability in metropolitan regions.

3.8. A New Approach to Land-use Structure

Urban growth has increasingly shaped the spatial relationship among land-use classes along metropolitan gradients (Antrop, 2004; Ferrara et al., 2016). Urbanization-driven socioeconomic transformations have determined an increased fragmentation of rural landscapes, resulting in mixed and heterogeneous fringe districts typical of medium-large metropolitan regions (Bhatta et al., 2010; Pili et al., 2017; Radeloff et al., 2005; Serra et al., 2008; Shrestha et al., 2012; Duvernoy et al., 2018). Agricultural and forest land are envisioned as fundamental land-use classes (i) buffering relict, non-urban fringe land from unregulated urban expansion, (ii) preserving fertile land from real estate speculation and (iii) assuring ecosystem stability and provision of key ecological services under increasing anthropogenic pressure (Allen, 2003; Colantoni et al., 2015; Kroeger and Casey, 2007; Simmons et al., 2016).

Recent land-use and land cover transformations are associated with different socioeconomic factors, which affect differently the spatial configuration, hierarchy and composition of landscapes negatively impacting ecosystem functioning and socio-environmental systems at large (Biasi et al., 2017; Christopoulou et al., 2007; Feranec et al., 2010; Frondoni et al., 2011). Results of these processes are the fragmented, mixed and ecologically-fragile landscapes, which are typically observed in metropolitan regions of advanced countries (Cecchini et al., 2018; Salvati et al., 2017). Mixed and fragmented landscapes are often combined with a greater social fragility of fringe districts (Christopoulou et al., 2007; Zambon et al., 2018), causing an unsustainable development leading to spatially-unbalanced economic development in the long run (Pili et al., 2017; Biasi et al., 2017; Cecchini et al., 2018; Franks, 2010; Zambon et al., 2017b).

Cited article

Zambon, I., Serra, P., Pili, S., Bernardini, V., Ferrara, C., Salvati, L. (2018). A New Approach To Land-Use Structure: Patch Perimeter Metrics As A Spatial Analysis Tool. Sustainability, 10(7), 1-17.

While landscape structure and configuration in Europe have been largely investigated from multiple perspectives (Agnoletti, 2014; Kasanko et al., 2006; Longhi and Musolesi, 2007; Turok and Mykhnenko, 2007), changes in the spatial relationship among land-uses - considered a process at the base of landscape modifications - have been explored occasionally (Bhatta et al., 2010). Approaches based on a 'landscape ecology' thinking were particularly common, proposing small- and large-scale analysis of landscape structure and configurations over time. Such approaches focused on a comprehensive analysis of patch size and shape, using multiple indexes (i.e. metrics) derived from (or inspired to) computational spatial analysis, complexity theory, entropy notion and fractal thinking. The analysis proposed in this work contributes originally to this issue by computing on individual patches and identifying the spatial relationships among land-use types through the analysis of patch boundaries and contact points. In other words, this study moves from a traditional landscape ecology approach grounded on patch size and shape metrics toward a more refined approach focusing on land-use spatial patterns and neighboring regimes, reconnecting a structural analysis of landscape with a functional analysis based on an explicit characterization of land-use and land cover categories.

Spatially-explicit theories based on a quantitative analysis of contact elements are common in physical and ecological science (Banerjee et al., 2014). Physical boundaries can designate

unambiguous limits of homogeneous areas/districts and land-use categories (e.g. urban, rural) (Franks, 2010; Allmendinger and Haughton, 2009). In spatial planning and urban studies, boundaries are considered the operational element separating different areas and land-use types (Forman, 2014.). At the same time, borders have been frequently reconnected with social issues, e.g. diversity, segregation, local neighborhoods (Jacobs, 1961; Schmid et al., 2009; Wessel, 2009); more recent studies conceptualize the 'boundary' notion in governance issues as related to landscape services (Opdam et al., 2015; Westerink et al., 2017). Although patch perimeter has been used as a benchmark in spatial studies (Cao et al., 2015; Hassan, 2017; Herold et al., 2003), literature on contact theory using landscape patches as elementary analysis' units and bearing in mind indicators that quantify properties and attributes of their boundaries (shared among different land-use) is relatively restricted (Batty and Longley, 1988). While being still poorly understood, the role of boundaries is decisive when characterizing metropolitan forms and functions.

Following spatial planning and governance of metropolitan regions, boundaries assumed jurisdictional, administrative, geographical and socioeconomic meanings (Christiansen and Jorgensen, 2000; Gregory, 2002; Jacquez et al., 2000), such as for participating government (Westerink et al., 2016), or are merely 'political borders' (Jones, 2009; Newman and Paasi, 1998). Consequently, boundaries impact (and are in turn influenced by) socio-environmental issues related to local communities, regional economic structures and the related land-use (Machlis and Tichnell, 1985). In this regard, urban morphology is a specific form of built-up patches with specific boundaries, reflecting a perimeter for each land-use type, useful for calculating e.g. its degree of irregularity based on fractal dimension (Batty and Longley, 1988). Since spatial planning usually manages local contexts according to an integral zoning approach, the functions of each urban patch/area may clearly emerge by considering its perimeter and therefore, the contact system with neighboring patches.

Based on these premises, this study provides an original approach to a joint structural and functional landscape analysis, introducing a new class of landscape metrics assessing basic features of patch perimeters. Specific computation on patch perimeters was carried out on fine-grained land-use maps covering homogeneously the European continent with the aim to characterize spatial patterns of neighbor patches, evidencing contact points and perimeter length between two (or more) land-use types. A detailed set of class- and landscape metrics were derived from such analysis. This approach appears complementary to classical landscape metrics and proved to be particularly useful to characterize complex, fragmented landscapes profiling metropolitan regions based on integrated evaluations of their structural (landscape) and functional (land-use) configuration. Spatial diversity was evaluated using the Shannon index applied to the composition of landscape bordering each patch.

A multivariate analysis was run to characterize distinctive spatial patterns of the selected metrics in four metropolitan regions of southern Europe that reflect different morphological configurations (Barcelona: compact, polycentric; Lisbon: dispersed, mono-centric; Rome: dispersed, poly-centric; Athens: compact, mono-centric). Results of this work will complement studies grounded on a classical landscape ecology approach (i.e. based on landscape metrics) with a functional analysis of land-use types assessing spatial neighboring patters. Findings will constitute a knowledge base advancing integration of urban studies, landscape ecology and spatial science,

offering relevant suggestions to renewed practices of sustainable management of fringe land in metropolitan regions.

3.8.1. Patch perimeter metrics as a spatial analysis tool

Four large metropolitan regions in southern Europe - three of which are capital cities - were considered in this study: Lisbon (Portugal), Barcelona (Spain), Rome (Italy), and Athens (Greece). For each city, the investigated area corresponds to the related 'Urban Atlas' region. 'Urban Atlas' is the major initiative dealing with sprawl monitoring all over Europe and represents an information tool for both assessment and urban policy analysis (EEA, 2010). According to Urban Atlas initiative, the boundaries of metropolitan regions were identified based on a comprehensive analysis of commuting patterns, reflecting central and peripheral locations in each city. Spatial domains defined according to Urban Atlas allow reliable comparisons on population, land-use and other key variables, which are homogeneous with relevant statistical areas defined by the Urban Audit, a Eurostat initiative aimed at providing a full collection of statistical data dealing specifically with metropolitan regions all over Europe.

The information used here was derived from Urban Atlas maps scaled 1:10,000 and produced on behalf of Land Copernicus initiative. Maps covered separately the metropolitan region of each city. All cities > 100,000 inhabitants in Europe were assumed in the initiative and urban boundaries were defined according to Eurostat Urban Audit classification of metropolitan regions in Europe, considering commuting patterns derived from the latest population census and studied at municipal scale. Urban Atlas maps provide a consistent and homogeneous information base as far as coverage, temporal acquisition of the original data, spatial resolution, and classification system are concerned. The resulting land-use nomenclature was articulated into 20 classes (Table 3.23), including 16 urban classes and 4 non-urban classes, providing a comprehensive description of land-use in European metropolitan regions.

Table 3.23. List of landscape variables considered in this study (variables from CUF to SPORT: patch perimeter length by land-use class in total patch perimeter).

Variable's name	Acronym
Continuous Urban Fabric (S.L. > 80%)	CUF
Discontinuous Dense Urban Fabric (S.L.: 50% - 80%)	DDUF
Discontinuous Medium Density Urban Fabric (S.L.: 30% - 50%)	DMDUF
Discontinuous Low-Density Urban Fabric (S.L.: 10% - 30%)	DLDUF
Discontinuous Very Low-Density Urban Fabric (S.L. < 10%)	DVLDUF
Industrial, commercial, public, military and private units	ICPMPU
Agricultural + Semi-natural areas + Wetlands	AGR
Isolated Structures	ISOL
Airports	AIRP
Construction sites	CON
Fast transit roads and associated land	FAST
Forests	FOR
Green urban areas	GREEN
Land without current use	LAND
Mineral extraction and dump sites	MINE
Other roads and associated lands	ROADS
Port areas	PORT

Railways and associated land	RAIL
Sports and leisure facilities	SPORT
Patch perimeter (m)	P
Patch size (m^2)	A
Perimeter to area ratio	P/A
Distance from downtown (m)	Dist
Pielou J evenness index	J

The statistical analysis was developed using patches as the elementary spatial unit. Urban and non-urban patches bordering each built-up patch were identified using ArcGIS (ESRI Inc., Redwoods, USA). A procedure based on 'zonal statistics', 'spatial analyst' and other ArcGIS 'toolbox' commands was developed with the aim to determine the total perimeter of each built-up patch and the share of each surrounding land class in the total perimeter. The percentage share of a given class perimeter in total patch perimeter was calculated for each patch classified according to the land-use nomenclature system reported in section 2.2. Diversity in the landscape surrounding each built-up parcel was assessed by computation on the share of each land-use class perimeter in total patch perimeter (pi) using the Shannon index (H') calculated as

$$H' = - \sum_{i=1}^{n} pi \log pi$$

Five ancillary variables were finally calculated at the patch scale with the objective to assess the impact of the local context on the composition of landscape surrounding each urban parcel: (i) linear distance from downtown (calculated determining the centroid of each patch and deriving the linear distance with a central place in the city: Platia Syndagmatos in Athens, Piazza Barberini in Rome, Plaza de Catalunia in Barcelona and Plaza do Commercio in Lisbon), (ii) elevation (a binary variable distinguishing lowland patches labeled with '0' from hilly and mountain patches labeled with '1'), (iii) patch size (logarithm), (iv) perimeter-to-area ratio and (v) percentage of sea coast bordering each patch, considering that all metropolitan regions investigated in this study include a (more or less extended) coastal district.

Descriptive statistics were computed with the aim to provide an advanced knowledge of the spatial distribution of landscape patches in the four metropolitan regions, using scatter plots that illustrate the average location of patches by land-use class (computing on patch centroids) and the mean distance from the respective city center.

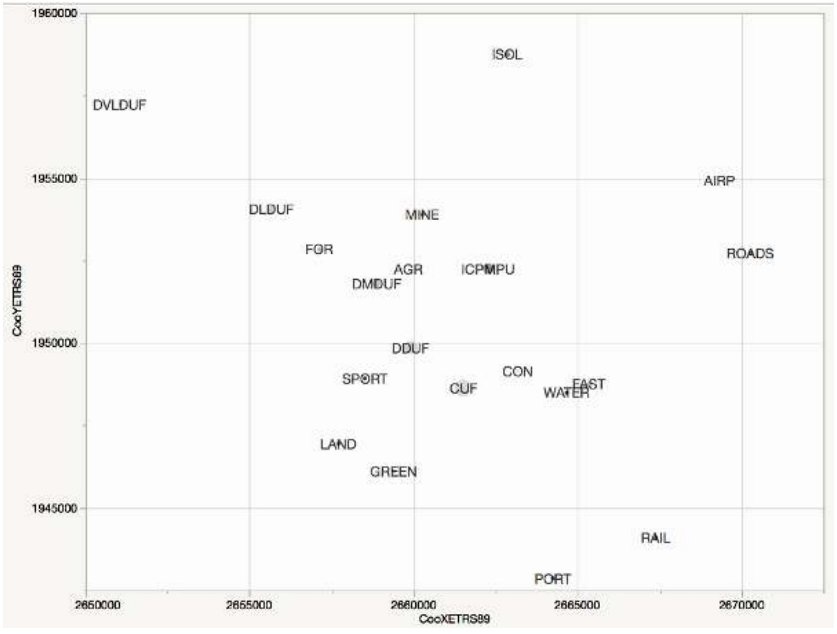
A Principal Component Analysis (PCA) was run on the matrix composed of land-use indicators resulting from the spatial analysis illustrated, with the objective to identify factors influencing the composition and structure of landscape around each investigated patch. To avoid multi-collinearity, the share of 'inland water' perimeter in total patch perimeter was considered as a supplementary variable in the PCA. As the PCA was based on the correlation matrix, components with eigenvalue > 1 have been analyzed for loading structure. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy, which tests whether the partial correlations among variables are small, and Bartlett's test of sphericity, which tests whether the correlation matrix is an identity matrix, have been used to assess the quality of PCA outputs. These tests indicate if the selected model is suited to analyze the original datasets. Statistical analysis was performed using Statistica 5.0 package (STAT software Inc., Tulsa, Oklahoma, USA).

Similarity in the spatial distribution of land-use classes bordering each patch was investigated using a two-way hierarchical clustering based on Euclidean distances and Ward's agglomeration rule and aggregating patches and indicators respectively on rows and columns. This analysis was aimed at identifying the interplay between the territorial context (e.g. topography, accessibility, urban gradient/human pressure) and landscape spatial structure based on the analysis of nearest neighboring land-use types. This examination can also improve further involvements dealing with the analysis of urban-rural gradient in interpreting land-use and land cover change (LUCC) (McDonnell and Hahs, 2008; Modica et al., 2012; Yang et al., 2010; Salvati and Carlucci, 2011).

After standardization of the input variables, a linear discriminant analysis was carried out separately for the 4 cities with the aim to discriminate spatial neighbor patterns for three basic classes of land-use (urban: code 1, agriculture: code 2, forest and natural land: code 3) using the same variables considered as input in the PCA (see above). A forward stepwise approach was adopted to identify and rank the most significant predictors discriminating among the three land-use classes assumed above using a F-to enter p-value of 0.01. To rank the importance of the different predictors identified by the stepwise procedure, results of each model were presented considering standardized coefficients and tests of significance (a F-statistic testing for the null-hypothesis of non-significant discriminant variable).

3.8.2. Basic characteristics of patches and nearest neighbor landscape

A statistical analysis of spatial distribution of landscape patches was proposed in Figure 3.28, outlining the average location of patches (centroid) by land-use class in each metropolitan region. In Lisbon, infrastructures (ports, roads, railways, airports), together with isolated settlements, display a peripheral location. More central locations were found for agricultural areas and forests. On average, compact and moderately dispersed settlements display central or semi-central locations. Land-use structure in Barcelona reveals, on average, more concentrated patches relegating agricultural areas, forests and road network to more peripheral locations. Continuous settlements occupy, on average, central places and discontinuous settlements illustrate a semi-central distribution. In Rome, most peripheral locations are occupied by discontinuous, low-density residential settlements, isolated settlements, green areas including suburban parks, airports, ports and water bodies. Compact and more dispersed settlements, agricultural areas, forests and road network occupy central or semi-central locations. In Athens, land-use distribution was quite heterogeneous over space, with peripheral locations occupied by infrastructures, medium-low density residential settlements, isolated settlements, water bodies and forests. Compact and discontinuous dense residential settlements, service and industrial settlements and agricultural areas locate preferentially in central or semi-central places.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DVLDUF
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CON
SPORT
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FAST
WATER
LAND
GREEN
RAIL
PORT
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CooYETRS89
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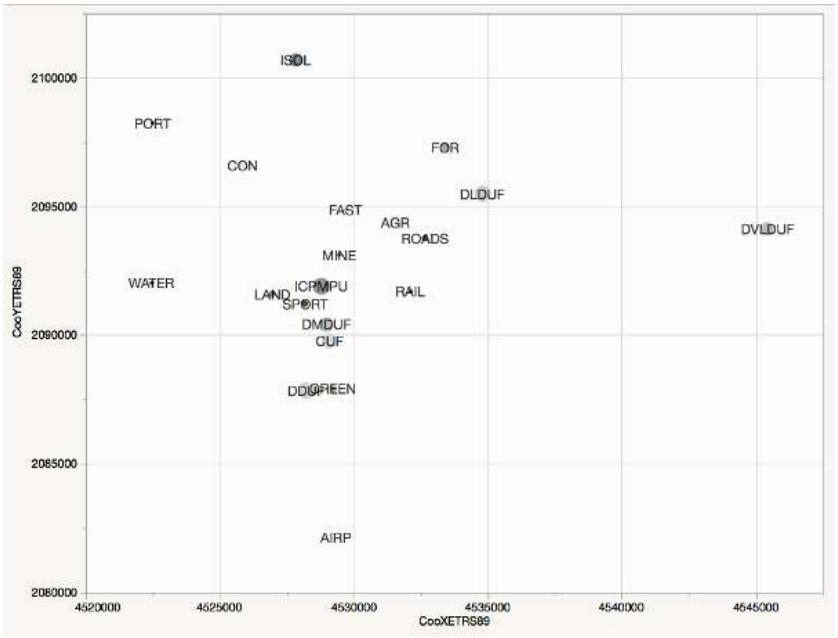
Lisbon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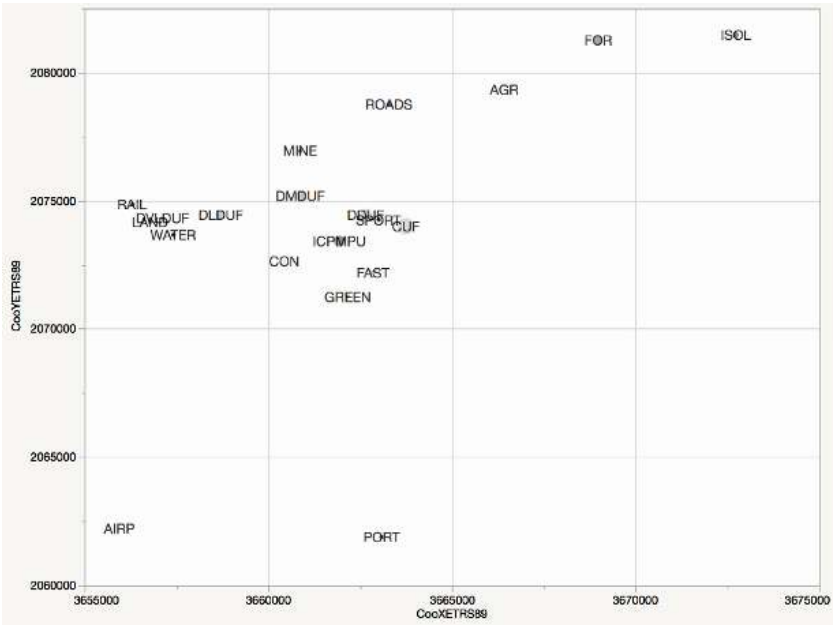
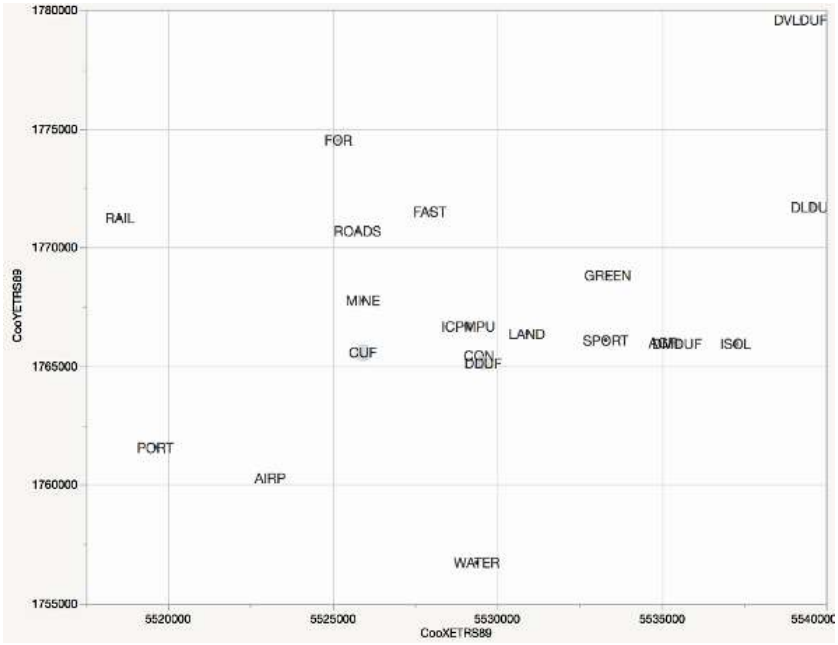
CooXETRS89

Rome



Barcelona



Athens

Figure 3.29. Spatial clustering of land-use classes in each metropolitan region.

A specific analysis of the spatial distribution of patches by land-use class and distance from downtown is reported in Figure 3.30. Land-use classes display, on average, a similar distribution along the urban gradient in all cities investigated, with a (more or less) evident variability possibly associated with place-specific factors. Compact urban fabric occupies central locations in Athens and semi-central locations in Barcelona, with Lisbon and Rome situating in-between. Variability along urban gradients is the highest in Barcelona and the lowest in Athens. Patches of dispersed, medium-low density residential urban fabric are situated relatively close to the inner city of Lisbon and more distant in Athens, Barcelona and Rome, with increasing variability and specific spatial patterns for medium-density and low-density settlements observed in Barcelona and Rome: as expected, medium-density settlements grew at lower distances from downtown than low-density settlements in these cities. Industrial, commercial and residential settlements define a very high spatial heterogeneity in all cities. Agricultural and forest patches display a substantially homogeneous

spatial distribution in Rome and Lisbon, with average distance from downtown ranging between 10 and 20 km and a more heterogeneous pattern in Barcelona and Athens.

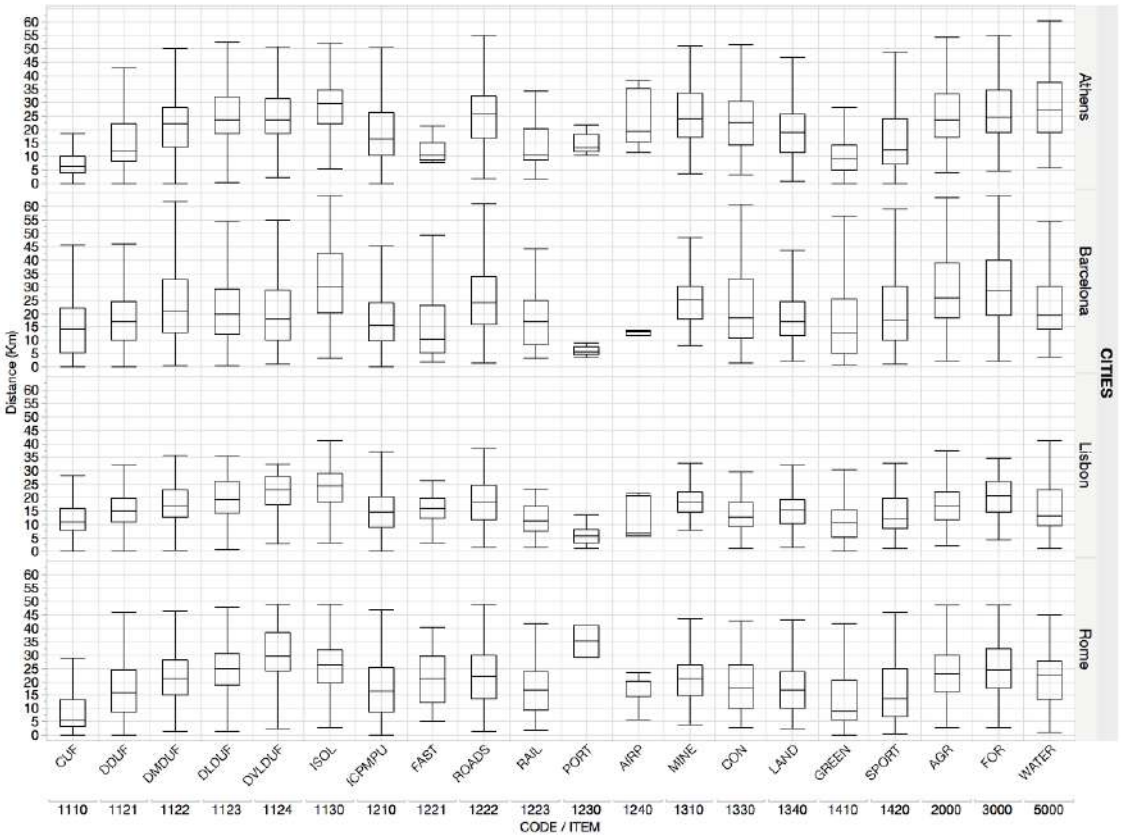
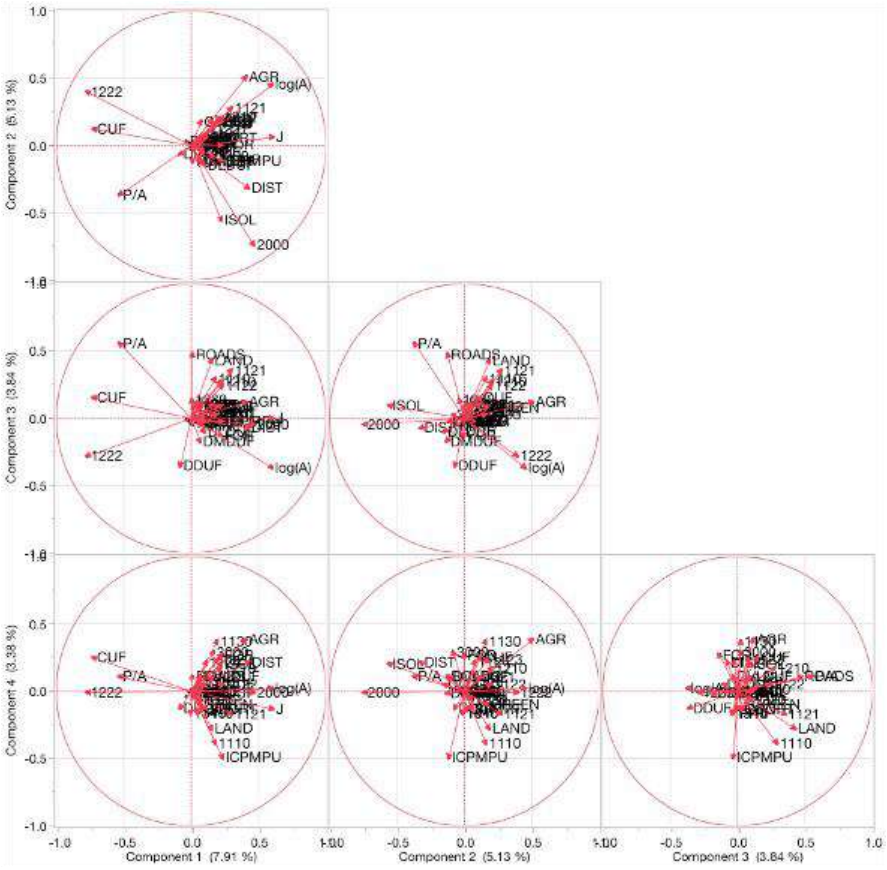
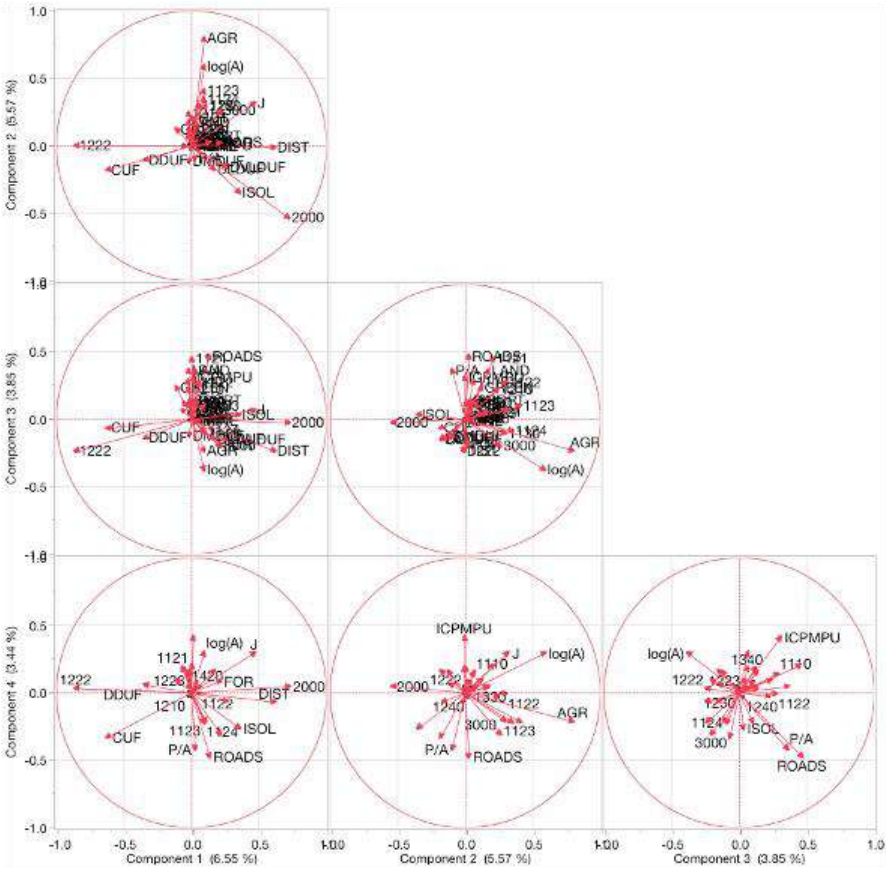


Figure 3.30. Distance of patches from the inner city by land-use class and metropolitan region.

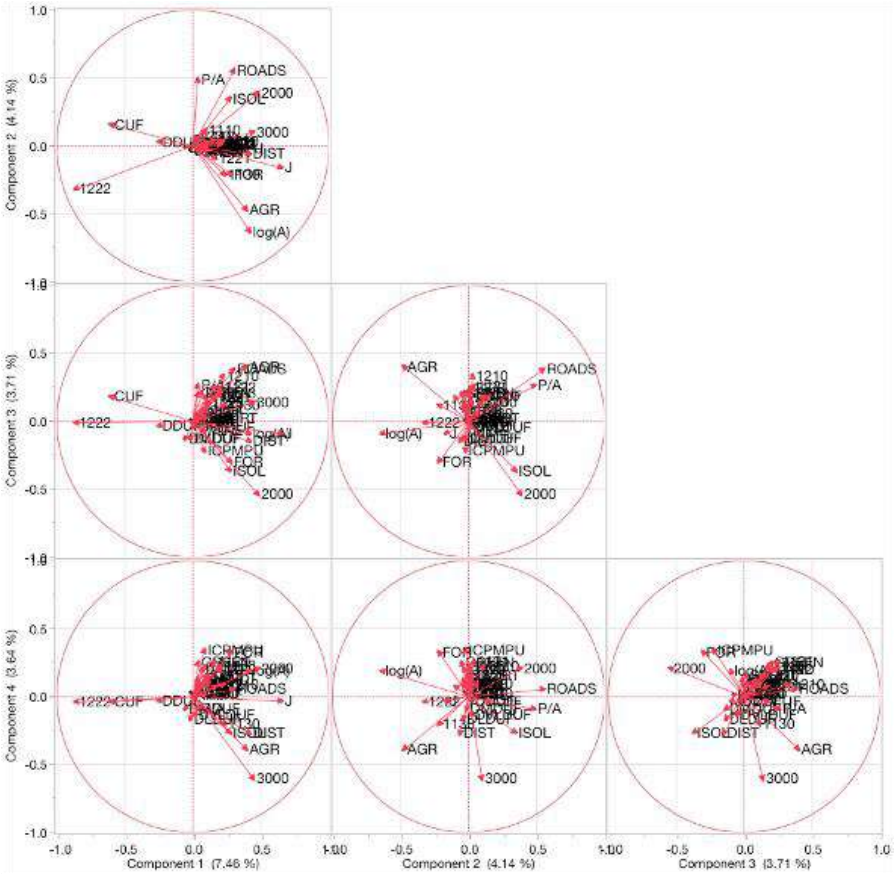
Results of a principal component analysis run on landscape indicators (patch perimeters and ancillary variables) indicate a substantial similarity in landscape patterns across metropolitan regions, with local specificities depending on certain associations among land-use types (Figure 3.31). The four principal components were extracted and compared among cities. In Lisbon, components 1 to 4 accounted for nearly 20% of cumulated variance, a relevant finding considering the high number of input variables. Components identify spatial gradients characterized by land-use polarizations in (i) compact urban fabric, non-residential urban fabric, agricultural land and infrastructure (component 1 vs 2), (ii) low-density urban fabric and road infrastructure (component 1 vs 3) and (iii) agricultural land and isolated buildings (component 1 vs 4). In Barcelona, components 1 to 4 accounted for nearly 19% of cumulated variance and identify a more polarized spatial distribution of compact urban fabric, natural areas (including agricultural land and forests), road network and isolated buildings in respect with other land-use classes. In Rome, a cumulated variance of 19% was explained by components 1 to 4, evidencing spatial polarizations between (i) agricultural land and discontinuous dense residential urban fabric and between (ii) compact urban fabric and isolated buildings. Moreover, patches devoted to agricultural have a very low perimeter-to-area ratio. In Athens, the first 4 components explain together more than 20% of the total matrix variance. Compact urban fabric and distance from downtown assume very high loadings on components 1 and 2, as expected in a mono-centric region, evidencing a spatial gradient distinguishing residential urban fabric from agricultural areas. Road network and isolated buildings reveal together a spatial distribution diverging from typical locations of cropland.


Component 1 (7.91 %)
Component 2 (5.13 %)
Component 3 (3.84 %)
Component 4 (3.38 %)
AGR
log(A)
1222
CUF
J
P/A
DIST
ISOL
2000
ROADS
LAND
DDUF
1130
1110
ICPMPU

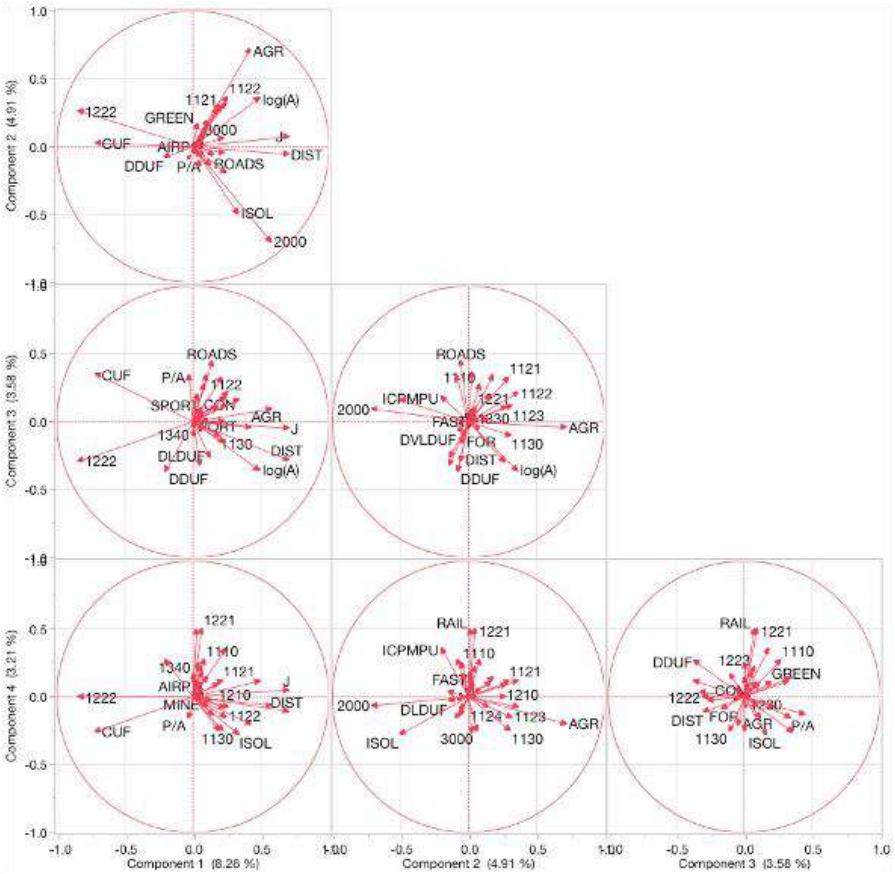
Lisbon


Component 1 (6.55 %)
Component 2 (5.57 %)
Component 3 (3.85 %)
Component 4 (3.44 %)
AGR
log(A)
1222
CUF
DDUF
DIST
ISOL
2000
ROADS
1123
3000
ICPMPU
1110
1122
1240
1340
1230
1124
FOR
1121
1210
P/A

Rome



Barcelona



Athens

Figure 3.31. Biplot of principal component analysis in the four metropolitan regions.

Hierarchical clustering explored similarities in the spatial structure of land-use surrounding landscape patches in the metropolitan regions (Figure 3.32). Four clusters were identified in Lisbon, distinguishing (i) linear infrastructures with a specific patch perimeter-to-area ratio from (ii) agricultural patches far from the inner city, (iii) forest land, water bodies, urban parks, land waiting for construction and non-residential urban fabric and finally (iv) residential urban fabric, both compact and dispersed. In Barcelona, tree clusters were identified, outlining similarities between (i) low-density residential urban fabric and linear infrastructures (from 1122 to 1222), (ii) natural land (agriculture + forest) and very low-density, discontinuous urban fabric (from code2 to 3000); the largest cluster (iii) include compact and semi-dense settlements, non-residential urban settlements, infrastructures and water bodies. In Rome, hierarchical clustering indicates three homogeneous groups: (i) discontinuous, low-density residential urban fabric and forest land (from CODE2 to 3000), (ii) agricultural land patches at increasingly high distances from downtown and (iii) the remaining variables including infrastructures, compact and semi-dense urban fabric, urban parks, land waiting for building and water bodies. Finally, Athens' spatial structure was characterized by two main clusters separating (i) low-density residential urban fabric, forests and agricultural land from (ii) compact urban fabric, other urban land-use, water bodies, infrastructures and urban parks.

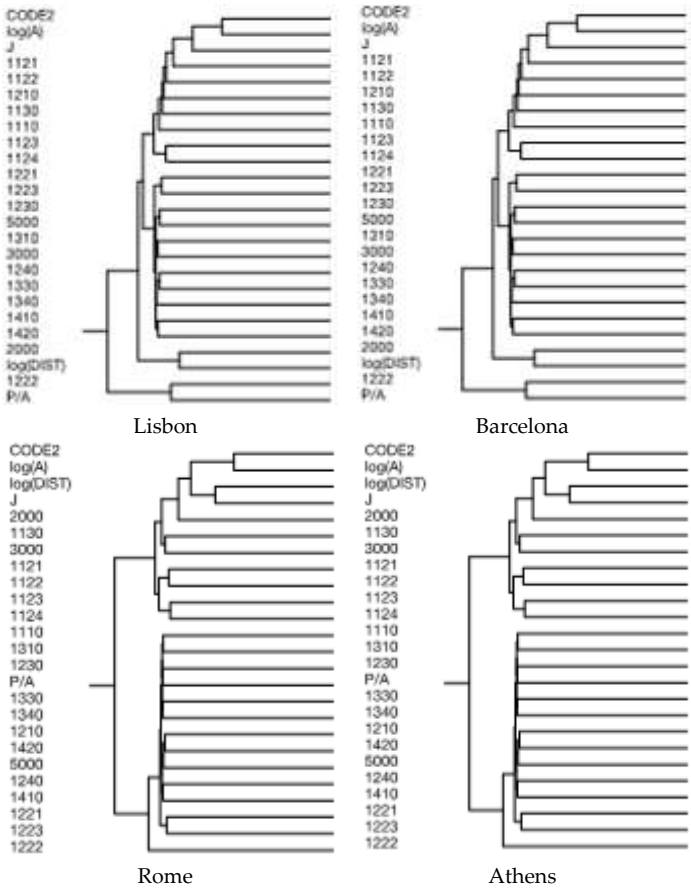


Figure 3.32. Hierarchical clustering of landscape and patch attributes in the four metropolitan regions (CODE2 indicates a dummy for elevation, see section 2.3).

A step-wise discriminant analysis was finally carried out with the aim to identify the land-use structure discriminating urban, agricultural and forest patches (Table 3.24) separately for each city. In Lisbon, the most relevant land-use classes identifying the nearest neighbor landscape structure of urban, agricultural and forest patches are discontinuous residential urban fabric, non-residential

urban fabric, linear infrastructures, urban parks, cropland and water bodies. A rather different context was observed in Barcelona, with the most relevant variables being compact urban fabric, linear infrastructures, urban parks, cropland and water bodies, indicating substantial differences in the urban structure of the two regions, more compact in Barcelona and relatively more dispersed in Lisbon. In Rome, most variables contribute significantly to discriminate urban from agricultural and forest patches; this indicate a very heterogeneous spatial structure, with no specific neighboring patterns. In Athens, residential urban areas (both compact and dispersed) are the most relevant variables discriminating among patch types, together with land waiting for building, urban parks and, to a lesser extent, cropland.

Table 3.24. Results of a step-wise linear discriminant analysis ranking variables according to their importance in the identification of patches with urban (code 1), agricultural (code 2) or forest (code 3) use by city (only significant F-to enter at $p < 0.001$ were shown).

Variable	Lisbon	Barcelona	Rome	Athens
1110		229	218	114
1121	508		52	695
1122	538		196	1549
1123	568		1053	1297
1124			1802	304
1130	1625	2290	2764	7148
1210	496	77		555
1221	403	81	185	
1222	638	5476	1345	5021
1310	148		90	132
1330			105	
1340	329	386	652	1269
1410	215	622	847	2069
1420				101
2000	1045	5252	2639	6627
3000			108	
5000	250	308	115	

3.8.3. Investigating landscape composition and land-use spatial structure

The analysis done introduces an original analysis investigating together landscape composition and land-use spatial structure. Each patch forming the investigated landscape was examined along its perimeter and its neighboring urban and non-urban areas, defining a specific landscape configuration in each city (Colantoni et al., 2016; Munafò et al., 2013). The theory of contact and the analysis of the adjacent mosaic proved to be fundamental to assess the degree of fragmentation or homogenization in each landscape. Under specific assumptions and case studies, the proposed methodology has assessed complexity of fringe landscapes (Frenkel, 2004). This approach is considered as complementary to classical landscape metrics and proved to be particularly useful to characterize complex, fragmented landscapes profiling metropolitan regions based an integrated evaluation of their structural (landscape) and functional (land-use) organization.

Using patch-level data based on perimeter's metrics, various processes of landscape transformation can be identified and described comprehensively (Carrion-Flores and Irwin, 2004). Results of the multivariate analysis run to characterize distinctive spatial patterns of the selected patch perimeter metrics identify different morphological configurations in the four metropolitan

regions, suggesting that the metric's ensemble adopted in this study is suitable to represent typical regional-scale landscape structures in a range of metropolitan configurations, from compact, polycentric cities (Barcelona) to dispersed, mono-centric cities (Lisbon). Interestingly, perimeter metrics assumed different values for each investigated land-use class, with peculiar characteristics associated to each city. For instance, land-use types assessing residential, discontinuous urban patches were associated to particularly high values of perimeter metrics, indicating place-specific patch fragmentation, a spatially-associated distribution of land-use types and a landscape complexity profile specific for each examined region. In this regard, multivariate analysis indicates substantial differences among cities, reflecting the range of morphological configurations described above (from compact mono-centric to dispersed polycentric) and suggesting that urban expansion is accompanied with multiple modifications in the use of the surrounding non-urban land. The computational approach proposed in this study and based on spatially-explicit metrics of landscape configuration and proximity reflects latent changes in local socio-environmental structures (Salvati et al., 2013a), suggesting that scattered urban expansion may determine a latent polarization in suburban areas with highly fragmented and more homogeneous landscapes (Carlucci et al., 2017; Cuadrado-Ciuraneta et al., 2017), respectively associated with mixed cropland and forest systems (Colantoni et al., 2015).

Place-specific contexts shaping the landscape structure that surrounds each studied patch were considered together with landscape-specific factors (e.g. patch size and shape, elevation, distance from the sea coast). Spatial variability in the physical boundaries among patches (indicating the nearest neighboring land-use spatial regime for each patch) is likely reflective of socio-spatial, demographic and economic evolutions that require specific investigation starting from the simplified results of the landscape analysis (Pili et al., 2017; Salvati and Gargiulo Morelli, 2014). For example, in compact cities (Athens, and a lesser extent, Barcelona), a higher proportion of natural land surrounding urban settlements during compact growth was associated with larger urban patches, while cropland increased at lower elevation and dominated non-urban landscapes around fringe settlements. The role of factors such as the distance from inner cities in shaping the structure of suburban landscapes is largely variable across cities - because of the different spatial organization of each metropolitan region - and the reverse pattern was observed for urban patch size.

Approaches based on patch perimeter metrics allow investigating together to form and functions of urban vs rural landscapes, representing effective tools that integrate practical knowledge based on high-resolution maps with a computational procedure following spatial analysis principles, under cross-section surveys or measurements repeated over time. A multivariate analysis of patch perimeter metrics may identify - better than other, more traditional, landscape ecology techniques - the latent interplay between landscape and local communities (demography, socio-spatial organization, economic structure) resulting in a specific profile of land-use configuration at each city (Salvati et al., 2013a). Changes in the spatial structure of peri-urban landscape are demonstrated to have implications concerning sustainable development and land management of fringe land (Carrion-Flores and Irwin, 2004; Zambon et al., 2017b; Monarca et al., 2008; Colantoni et al., 2016; Zambon et al., 2015). Comparative investigation of metropolitan evolution based on spatio-temporal trends in neighboring patches' structure and other morphological features of landscapes proved to be a consistent information when designing policies aimed at sustainable land management and urban control (Marraccini et al., 2015). In these regards,

policies integrating spatial planning and developmental measures can influence specific form-function relationships characterizing contemporary cities and their landscape (Longhi and Musolesi, 2007). The base of knowledge derived from empirical results of the proposed analysis at both patch and landscape scales are pertinent from both the positive and normative viewpoints, enlightening planning decisions and advancing ecological and social disciplines (Colantoni et al., 2016; Salvati, 2014b).

3.8.4. Comprehensive indication of evolving landscapes and land-use changes

A comprehensive investigation of spatial structures, such as those characterizing land-use, is particularly important to provide a comprehensive overview of evolving landscapes and land-use changes at both metropolitan and local scale (Carrion-Flores and Irwin, 2004; Mallinis et al., 2014). Based on the perimeter of each patch, the surrounding patches having a spatial contact with it express a specific landscape mosaic (Forman, 2014), reflecting (apparent and latent) relationships among land-use and outlining intrinsic processes such as urbanization, land consumption, non-urban land abandonment, forestation (Ferrara et al., 2016; Radeloff et al., 2005; Shrestha et al., 2012; Ferrara et al., 2014), among others. Such knowledge is a base to a sustainable development agenda for European countries. Newly emerging landscape forms, better detected using innovative approaches as the example provided in this study, require an original analysis of land-use relationships, pointing out the significance of an enduring assessment of landscape alterations, and then supporting and orienting convenient conservation policies (Simmons et al., 2016; Agnoletti, 2014; Laidley, 2015). Comparative analysis is particularly suited to clarify the socio-environmental consequences of land-use transformations and landscape fragmentation in ecologically-fragile and socially-divided European metropolitan regions under increasing anthropogenic pressure, with the aim of achieving a sustainable model of urban growth (Grekousis et al., 2013), more effective planning policies and strategies encouraging a land-saving economic development.

3.9. Population matters over time

Polycentrism is a spatial structure characterizing several regional systems worldwide (Salvati and De Rosa, 2014; Schneider and Woodcock, 2008; Hall, 2009). Polycentric regions are based on a dense infrastructural network of urban centers having a similar or different demographic size, a more balanced economic power, and concentration of key socioeconomic functions (Dujardin et al., 2008; Hatz, 2009; Meijers, 2008; Parr, 2004; Salvati, 2014b). Population and employment sub-centers have emerged in locations more or less close to central cities during the long-lasting transformation from mono-centric to polycentric structures (Salvati and De Rosa, 2014; Hall, 2009; Salvati, 2014b; Cowell, 2010; Faludi, 2005; Longhi and Musolesi, 2007; Maloutas, 2007; Salvati and Carlucci, 2016; Salvati and Serra, 2016; Salvati et al., 2013a; Servillo and Russo, 2017; Ward, 2008; Ward, 2010). Regional and place-specific factors shaping distinctive patterns of urban growth made identification and characterization of mono-centric and polycentric structures sometimes difficult and vague (Kasanko et al., 2006). Defining impacts and consequences of polycentric development on socioeconomic dynamics are even more problematic, since urban cycles diverge largely across regions, in both advanced economies and emerging countries (Cuadrado-Ciuraneta et al., 2017; Kazemzadeh-Zow et al., 2017; Sarvestani et al., 2011).

Cited article

Mariani, F., Zambon, I., Salvati L. (2019). Population Matters: Identifying Metropolitan Sub-Centers From Diachronic Density-Distance Curves, 1960–2010. Sustainability, 10(12), 4653.

While population density, urban form, and socioeconomic functions are demonstrated to be important variables influencing metropolitan expansion, analysis of polycentric development appears increasingly complex due to multiple interacting factors (Salvati and De Rosa, 2014). Approaches that integrate morphological and functional issues (Salvati, 2014b; Colantoni et al., 2015; Neuman, 2005) were proposed with the aim to identify polycentric patterns of urban growth. However, complete lack (or partial availability) of comparable, high-resolution geo-spatial information at different spatial scales—from local to regional—prevent methodological generalization and limit regional comparisons (Roca Cladera et al., 2009; Veneri, 2013; Gilli, 2009). Urban expansion has been routinely assessed through a linear model simulating a negative relationship between population density and the distance from a central place (Vega and Reynolds-Feighan, 2008; Duvernoy et al., 2018; Pili et al., 2017). This relationship identifies a classical mono-centric model, with density of population, workers, or activities decreasing linearly with the distance from a central location due to agglomeration and scale factors, accessibility and land prices declining along urban gradients (Bonifazi and Heins, 2003; Haase and Nuissl, 2011). In this context, metropolitan sub-centers have been frequently considered an early sign of a truly polycentric and more spatially-balanced urban development, and were identified considering separately population, employment, activities, or other functions (Veneri, 2013; Gilli, 2009; Vega and Reynolds-Feighan, 2008). Deviations from such linear models may indicate a progressive shift toward more scattered (and less centralized) spatial patterns and are usually associated with consolidation of sub-centers attracting population and economic activities (Díaz-Pacheco et al., 2014; Muñiz et al., 2003; Weber and Puissant, 2003). In this regard, spatially-persistent, positive deviations from a density-distance linear trend are considered an honest signal of formation (and/or consolidation) of sub-centers across metropolitan regions (Salvati and Carlucci, 2016).

Being shaped by increasingly complex and locally-based socioeconomic processes, metropolitan expansion in Europe has resulted in a drastic transformation of spatial structures and land use. Polycentric development in this region was mainly based on processes of residential and industrial decentralization characterizing the most recent evolution of metropolitan systems (Boussauw et al., 2018; Zambon et al., 2017a). With impacts of polycentric development shaping regional systems' resilience to external shocks, a multi-level and multi-scale policy strategy is required to promote environmental sustainability, local competitiveness, and social cohesion in polycentric regions (Colantoni et al., 2016). However, while the concept of polycentric development is recognized as a key policy goal in the European Spatial Development Perspective (ESDP) (ESPON, 2014; ì Roy, 2009; Vasanen, 2012), applicability and effectiveness of measures promoting a truly polycentric and spatially-balanced development are possibly limited by settlement structures with a marked gap between urban and rural areas and a centralized spatial organization of socioeconomic functions, deriving from a mostly compact and dense long-term development (Meijers, 2008; Pili et al., 2017; Salvati et al., 2018). These conditions are particularly important in a policy-oriented analysis of polycentric development for metropolitan regions in southern Europe, displaying a relatively slow shift from strictly mono-centric structures to more polycentric spatial assets (Zambon et al., 2017a).

To investigate shifts from mono-centric structures towards polycentric spatial configurations in originally compact and dense metropolitan regions, a simplified procedure was introduced that identifies population sub-centers and evaluates spatial patterns of population growth—as a proxy of urban growth—over a relatively long time period. This procedure is based on a spatially-explicit analysis of the standardized residuals from a linear (ordinary least square) model that assesses the relationship between population density and the distance from a central location for each investigated region, under the hypotheses that (i) a mono-centric spatial structure is characterized by a perfectly linear relationship between the two variables and that (ii) population sub-centers—considered early signals of polycentric structures—are characterized by high and positive regression residuals. The proposed approach fixes a dynamic threshold for standardized residuals with the aim to identify and profile candidate sub-central locations.

With this approach, population sub-centers were identified over a relatively long time period (1960-2010) in three large metropolitan regions of Mediterranean Europe (Barcelona, Rome, Athens) using easily accessible data on total resident population derived from official censuses held every ten years at the desired spatial scale (municipalities in this case). On average, southern European urban agglomerations are considered more compact and denser than Western and Northern European counterparts, with a central city dominating the regional hierarchy of towns and minor settlements (Salvati et al., 2013b). Although cities in southern Europe have traditionally displayed similar (compact) morphologies and (diversified) socioeconomic structures (Delladetsima, 2006; Leontidou, 1990), the most recent expansion of such cities was characterized by 'individual' growth paths determining uniquely dispersed and highly fragmented spatial structures (Schneider and Woodcock, 2008; Faludi, 2005; Colantoni et al., 2015; De Muro et al., 2011; Salvati, 2013). Nowadays, several cities in southern Europe may represent emblematic cases of urban growth based on 'individualized' transitions toward a polycentric regional structure (Salvati and De Rosa, 2014; Salvati, 2014a). In this regard, a comprehensive investigation of population sub-center dynamics over time may benefit from a comparative analysis of socioeconomic transitions distinguishing compact mono-centric models (Athens) from semi-dense and spatially-discontinuous configurations

(Rome) and moderately polycentric (dense) urban structures (Barcelona) (Salvati et al., 2016a; Zambon et al., 2017b, 2018).

3.9.1. Identifying metropolitan sub-centers

The methodology was composed of several phases. After defining the three metropolitan regions in the analysis (Barcelona in Spain, Rome in Italy, and Athens in Greece), the description of statistical data and the spatial unit of analysis identified indicators and variables useful for comparing the study contexts. Then, a statistical analysis focused on a multi-step analytical outline, with the aim of (i) evaluating long-term, individual paths of urban expansion in the three cities and (ii) recognizing population sub-centers. Correspondingly, regression models were used as simplified tools, examining the relationship amongst a dependent variable and one (or more) predictor(s).

The study area included three metropolitan regions in southern Europe: Barcelona (Spain), Rome (Italy), and Athens (Greece). Considering territorial divisions based on administrative boundaries, broad regions surrounding the central city were selected as the study area with the aim to assess long-term spatial changes in population distribution, as shown in Figure 3.33: (i) Barcelona's province, (ii) Rome's province, and (iii) a large part of the administrative Attica region (including Athens, Piraeus, mainland municipalities, and Salamina island, and excluding mainland and island municipalities located in the geographical region of Peloponnese).

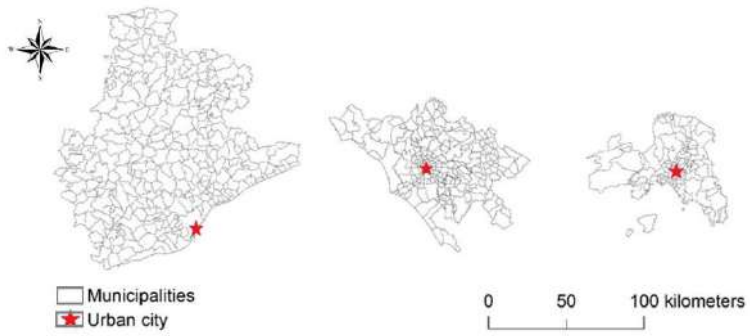


Figure 3.33. Maps illustrating the administrative boundaries (municipalities) of the three study areas (left: Barcelona, middle: Rome, right: Athens).

Being relatively stable and easily recognized by non-technical stakeholders, administrative boundaries were preferred to other territorial classifications with the objective to analyze comparative changes in the spatial distribution of the population for the whole study period (Salvati, 2014a). The administrative borders adopted in this study correspond to the NUTS-3 level of the nomenclature of the European Territorial Statistics adopted by Eurostat (see the official Eurostat website at https://ec.europa.eu/eurostat/web/nuts/background), a harmonized system of administrative units all over Europe. The study period covers a relatively long time period in the second half of the last century and reflects complex urban dynamics shifting from the massive demographic expansion of the 1960s and the 1970s (associated with compact, mono-centric development of central cities and suburbs) to population shrinkage (associated with a more dispersed expansion of settlements in peri-urban districts) typical of the 2000s. A basic description of the three case studies considering land area, number of spatial units, population density and growth over time is reported in Table 3.25.

Table 3.25. Basic characteristics of the three study areas.

Variables	Barcelona	Rome	Athens
Land area (km^2)	7725	5382	3025
Population density (inhabitants/km^2), 1960	372	516	669
Population density (inhabitants/km^2), 2010	716	764	1249
Annual population growth (%), 1960-2010	1.8	1.0	1.7
No. Municipalities/spatial units	311	235	115

Barcelona's province encompasses Barcelona's metropolitan region and includes 311 municipalities that administer nearly 7725 km^2 of land. Most of the province's area still consists of agricultural and natural land cover; urban areas are concentrated around Barcelona and are in the most accessible flat locations (Zambon et al., 2017b). The productive structure of the region is characterized by traditional and advanced services; while Barcelona concentrates tertiary activities with high value added, the city hosts a relevant economic base specialized in the manufacturing, metallurgical, chemical, and pharmaceutical sectors (Dura-Guimera, 2003). Rome's province is now officially designed as the 'metropolitan area of Rome' (following the prescription of a national Italian law from 2009) and covers nearly 5355 km^2 of land. The region is partitioned in 121 local municipalities that administer a relatively heterogeneous territory, with fragmented semi-natural landscapes that contrast with the compactness of the historical city of Rome, where upper socioeconomic functions are concentrated (Biasi et al., 2015; Salvati and Carlucci, 2011; Salvati et al., 2015a). The city provides traditional and advanced services and thrives on the retail trade and tourism. Rome's modern expansion was driven by service expansion instead of industrial development. The industrial sector is characterized by medium- and small-sized enterprises, except for the high-tech industry, located in sparse peri-urban districts south and east of Rome (Di Feliciantonio and Salvati, 2015).

The Athens region consists of steep land bordering the Greater Athens area—a continuous conurbation of residential-service settlements occupying a relatively flat area. Attica's economy is oriented toward advanced and traditional services (Rontos et al., 2016) concentrated in both Athens (communication, finance, banking, insurance, and real estate) and Piraeus (transport, logistics, and trade). The last Olympics (2004) had a pivotal impact on urban development, attracting public and private investments and promoting road and railway infrastructure (Colantoni et al., 2015; Delladetsima, 2006).

The study analyzed population data derived from the National Census of Population and Households carried out in 6 waves every 10 years on behalf of the respective National Statistical Authority (Instituto Nacional de Estadistica: INE in Spain (www.ine.es), Istituto Nazionale di Statistica: ISTAT in Italy (www.istat.it), and Hellenic Statistical Authority: ELSTAT (www.statistics.gr)). The study years were 1960 in Barcelona (or 1961 in Rome and Athens), 1970 (or 1971), 1980 (or 1981), 1990 (or 1991), 2000 (or 2001), and 2010 (or 2011).

Municipalities and homogeneous economic districts were frequently adopted as the elementary analysis' unit in a spatially-explicit analysis of urbanization, demographic transformations, and regional economic change (Salvati and Carlucci, 2016; Muñiz et al., 2003). Criticism was raised on their relevance for evaluation of population dynamics and coherent urban growth trajectories, municipalities, and other spatially-disaggregated administrative units (Salvati and Carlucci, 2011).

However, these units allow a detailed investigation of population density over a relatively long-time interval, due to homogeneous and standardized census data available for past decades (Salvati and Serra, 2016).

Municipal-level population data allow a comparative investigation of urban dynamics at both regional and local scales; integration with external data sources producing socioeconomic information relevant to regional studies is possible at such spatial scales. Integrated information on urban growth and population dynamics are more easily comprehensible for policy-makers, planners, practitioners, and non-technical users. In the three Mediterranean countries considered, municipalities are taken as the local authority defining (or contributing to define) land zoning. More specifically, municipal councils fix building volume, settlement size and shape, make decisions on land taxation regimes, and influence with their decisions other socioeconomic factors that influence the spatial distribution of population, ultimately determining population density over relatively vast areas (Giannakourou, 2005; Gospodini, 2006; Gospodini, 2009). In this regard, municipalities are a relevant spatial domain for both urban and regional planning (Guérois and Pumain, 2008) and for this reason, are adopted as the homogeneous analysis' domain. Considering the exceptional size of Rome's municipality (1285 km^2), this area was partitioned into 115 districts oriented along the urban gradient (Salvati et al., 2013b).

Population density was calculated from data quantifying resident population at a municipal scale and a municipal area (km^2), collected on behalf of the General Census of Population carried out in each country once per decade, 1960-2010 (or 1961-2011). Data were analyzed consistently for Barcelona, Rome, and Athens with the aim to assess changes over time in the spatial distribution of population across each region, as show in Figure 3.34.

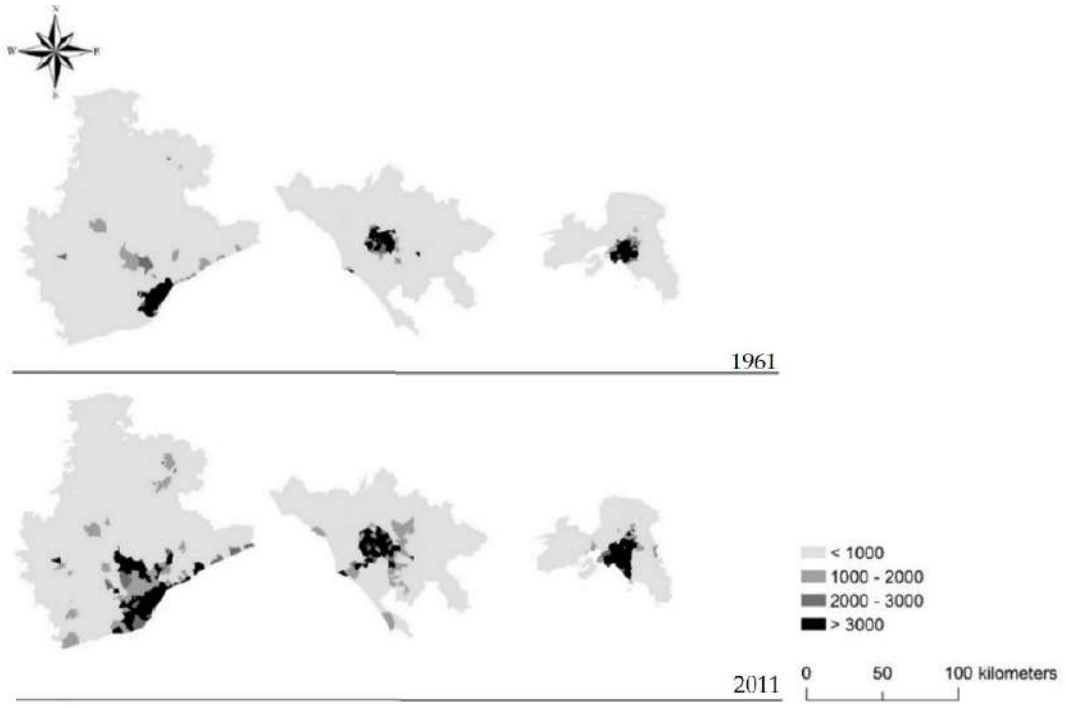


Figure 3.34. Maps illustrating population density (inhabitants/km^2) at the beginning (1961: up) and the end (2011: bottom) of the study period in Barcelona (left), Rome (middle), and Athens (right).

A multi-step analytical framework was proposed in this study with the final objectives (i) to assess long-term, individual paths of urban expansion in the three cities and (ii) to identify population sub-centers. Identification of sub-centers was based on a spatially-explicit analysis of standardized residuals from a specified regression model. Regression models are simplified tools investigating the relationship between a dependent variable and one (or more) predictor(s). Under the assumption that spatial variability in population density along urban gradients is a proxy of long-term urban growth (Salvati, 2014a), a log-linear regression was run to quantify the linkage between the dependent variable (population density, inhabitants/km^2) and a predictor (distance from a central place, km) in each city (Muñiz et al., 2003) according to the equation:

$$\log(Y) = ⊚ + ⊚\log(X) + e \quad (1)$$

where Y is population density, X is the distance from a central place in each city (see Section 2.4), ⊚ and ⊚ are respectively model's intercept and slope, and e is the regression error, estimated through the standardized distance of the model's prediction from the observed value (regression residual). Ordinary least squares regressions were estimated separately for each city and time point, using adjusted R2 as a measure of the model's goodness of fit. Relevance of each regression coefficient was based on computation of a t-statistic testing for significant coefficients at $p < 0.001$. Earlier studies (Salvati, 2014a) illustrated that a diachronic analysis of regression coefficients over a sufficiently long time period allows identification of individual paths of urban expansion.

3.9.2. Mapping population concentration

Each municipality was classified according to the standardized value of the regression residual calculated from the respective model run by year. Positive residuals indicate a population concentration differing largely from what is predicted by the respective model (an important precondition when identifying sub-central locations in a metropolitan region). A standardized residual > 1 was considered as a condition identifying a municipality with a population density deviating significantly from the model's expectation. Specific maps represent the spatial distribution of standardized residuals by year and city. An average (standardized) residual was finally calculated for each spatial domain and region considering the residual's values observed over the study period (n = 6 years), a relatively long-time interval encompassing different urban phases and distinct economic cycles. Municipalities with an average residual >1 were considered as population sub-centers based on the assumption that sub-centers are characterized by a systematically higher population concentration than the model's prediction.

3.9.3. Identifying population sub-centers in Barcelona, Rome, Athens

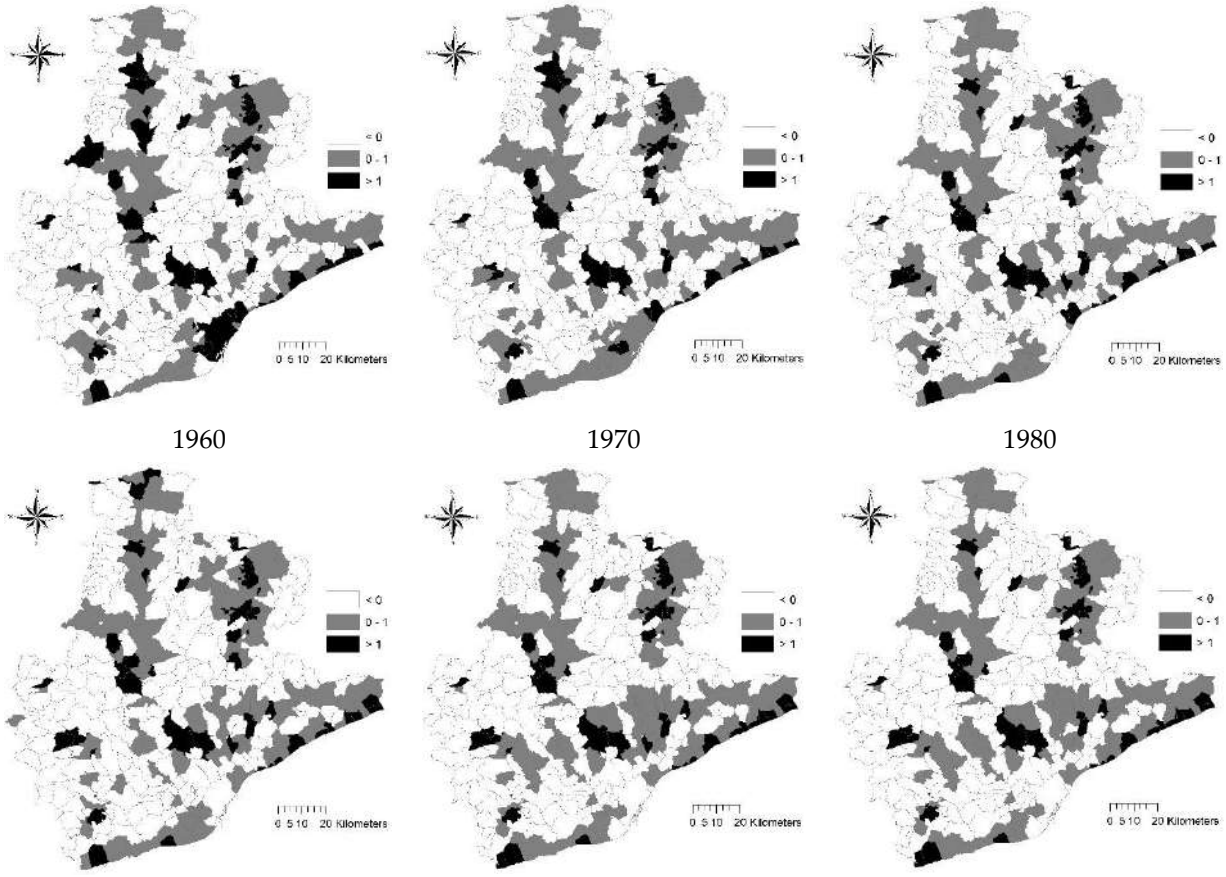
Table 3.26 reports the results of the regression model (Equation (1) separately for each area and year. The models' goodness of fit was high and statistically significant and increased over time for all cities. For Barcelona, the adjusted R2 of the model regressions increased from 0.33 (1960) to 0.51 (2010). The regression intercept increased from 4.28 (1960) to 6.19 (2010), indicating urban expansion. The regression slope decreased from −1.52 (1960) to −2.54 (2010). This trend evidenced an increasing gap in population concentration between urban and rural areas.

Table 3.26. Results of log-linear regression model (Equation (1)) for each investigated region with population density as the dependent variable and the distance of each spatial unit (municipality) from the respective inner city as the predictor (regression coefficients are all significant at $p < 0.001$).

Year	Intercept	Slope	Adj-R^2	Intercept	Slope	Adj-R^2	Intercept	Slope	Adj-R^2
	Barcelona			*Rome*			*Athens*		
1960	4.28(0.20)	−1.52(0.12)	0.33	2.57(0.10)	−1.69(0.08)	0.67	5.52(0.16)	−2.64(0.14)	0.75
1970	5.05(0.22)	−1.98(0.14)	0.40	2.56(0.11)	−1.66(0.08)	0.63	5.85(0.16)	−2.80(0.13)	0.79
1980	5.54(0.24)	−2.27(0.15)	0.43	2.60(0.11)	−1.62(0.08)	0.62	5.92(0.15)	−2.72(0.13)	0.79
1990	5.78(0.24)	−2.40(0.15)	0.47	2.58(0.10)	−1.56(0.08)	0.61	5.84(0.14)	−2.54(0.12)	0.79
2000	6.02(0.23)	−2.49(0.14)	0.50	2.54(0.10)	−1.51(0.08)	0.59	5.76(0.14)	−2.39(0.12)	0.78
2010	6.19(0.23)	−2.54(0.14)	0.51	2.59(0.10)	−1.45(0.08)	0.60	5.76(0.14)	−2.36(0.12)	0.77

For Rome, the adjusted R2 decreased from 0.67 (1961) to 0.60 (2011). Model's intercept increased moderately up to 1981 (2.60), decreasing slightly in the subsequent decades. The regression slope declined progressively from −1.69 (1961) to −1.45 (2011). For Athens, the adjusted R2 of log-linear models increased up to 1991 (0.79) declining in 2001 and 2011. The regression intercept increased from 5.52 (1961) to 5.76 (2011), with a peak in 1981 (5.92), indicating a latent process of densification up to 1981 and a de-centralized expansion afterwards. Regression slopes reach a peak (−2.80 in 1971) that reflects settlement densification in both Athens and Piraeus.

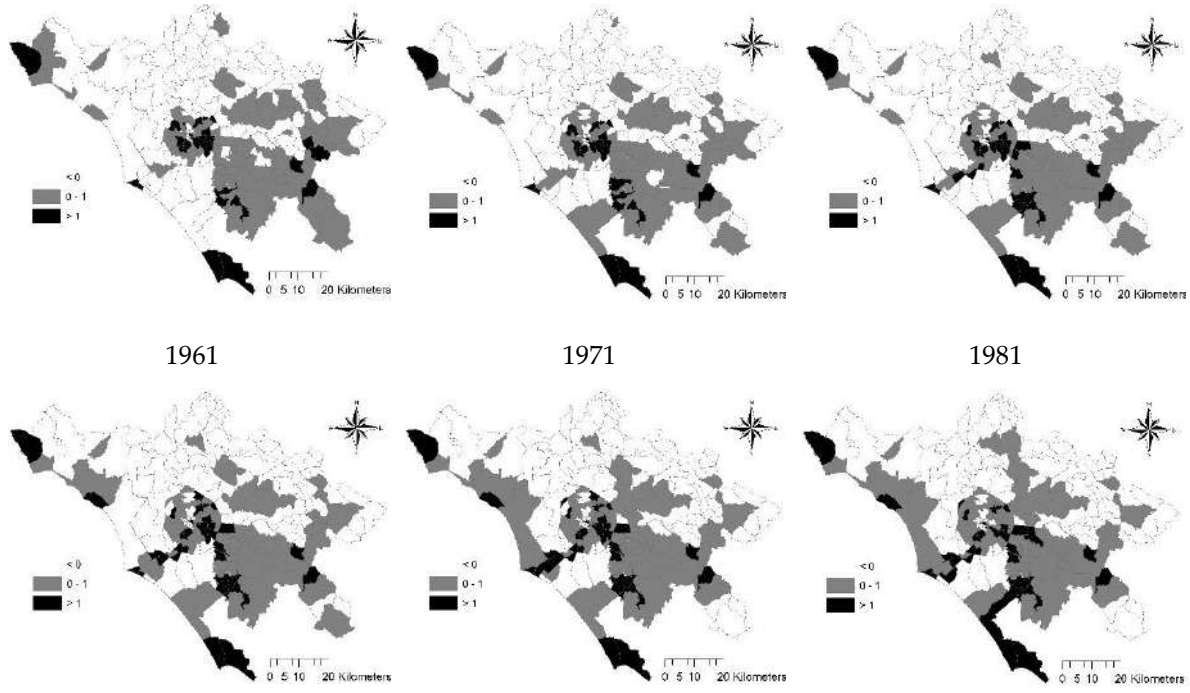
The spatial distribution of the standardized residuals from the log-linear model for Barcelona is illustrated in Figure 3.35. Standardized residuals >1 identified (i) coastal municipalities surrounding Barcelona and (ii) inland municipalities situated along the major transport routes to central Spain (Zaragoza) and the Pyrenees mountains. The first group include towns like Matarò, Sitges, and Vilanova i la Geltrù; the second group include towns like Sabadell, Terrassa, Granollers, Sant Cugat, Martorell, Rubì, Manresa, Vic, and Berga. Some of these locations were classified as residential/employment sub-centers in earlier studies. Inland places like Manresa, Vic, and Berga were characterized as head towns of (more or less) wide rural districts functionally connected with (but physically separated from) Barcelona. Interestingly, Barcelona and the neighboring municipalities (e.g., Badalona) received highly positive residuals in 1961 only, indicating a substantial change from a more centralized model to a de-centralized structure with sub-centers consolidating at distances progressively further away from the central city. The spatial distribution of the standardized residuals from the model for Rome is illustrated in Figure 3.36. Standardized residuals >1 were more scattered over space than in Barcelona and identify different clusters of municipalities: (i) peripheral districts belonging to Rome's agglomeration (including the coastal town of Ostia, belonging to Rome's municipalities but physically distinct from the main city and at a distance of more than 20 km from the city center), (ii) coastal municipalities at distances between 30 km and 50 km from Rome (including towns such as Civitavecchia and Anzio-Nettuno, with a leading role for the surrounding rural district), and (iii) internal municipalities situated in the Castelli Romani district, a traditional rural territory where some locations consolidated as local centers are attracting population and employment. As in Barcelona, peripheral districts in Rome received residuals progressively less positive over time.



1960 1970 1980

1990 2000 2010

Figure 3.35. Spatial distribution of the standardized residuals from a regression model by year in Barcelona.



1961 1971 1981

1991 2001 2011

Figure 3.36. Spatial distribution of the standardized residuals from a regression model by year in Rome.

The spatial distribution of the standardized residuals of the model for Athens is illustrated in Figure 3.37. Municipalities with standardized residuals >1 were relatively few and scattered over space compared with both Rome and Barcelona. Two groups of municipalities were detected: (i) peripheral districts belonging to the Greater Athens area and mainly situated in the Piraeus prefecture and in a district north-east of Athens experiencing rapid urban expansion since the 1980s, and (ii) coastal municipalities west, south-east, and north of Athens, at distances between 30 km and 50 km from downtown (Lavrio, Oropos, Rafina). As in Barcelona, central municipalities around Athens had negative (or slightly positive) standardized residuals. As in Rome, peripheral districts in Athens received standardized residuals progressively less positive over time. Considering municipalities with standardized residuals systematically above 1 over the study period as candidate sub-centers, as shown in Figure 3.38, a differentiated spatial pattern emerges for the three cities. For Barcelona, municipalities with average residuals >1 were identified along the sea coast (e.g., Matarò), the outer ring of Barcelona (Sabadell, Terrassa), and in more internal locations along the highways to Zaragoza (Manresa) and Pyrenees (Vic, Berga). Potential sub-centers in Rome were mainly located in the outer city ring (Ostia, Ciampino, and surrounding districts), along the coastal line (Civitavecchia, Ladispoli, Anzio) and in more internal locations (Frascati, Albano, Marino in Castelli Romani districts and Colleferro, along the highway to Naples). Candidate sub-centers in Athens were identified as specific municipalities in the Greater Athens area (Kifissià, Glyfada), and along the sea coast farther away from Athens (Elefsis, Lavrio, Oropos).

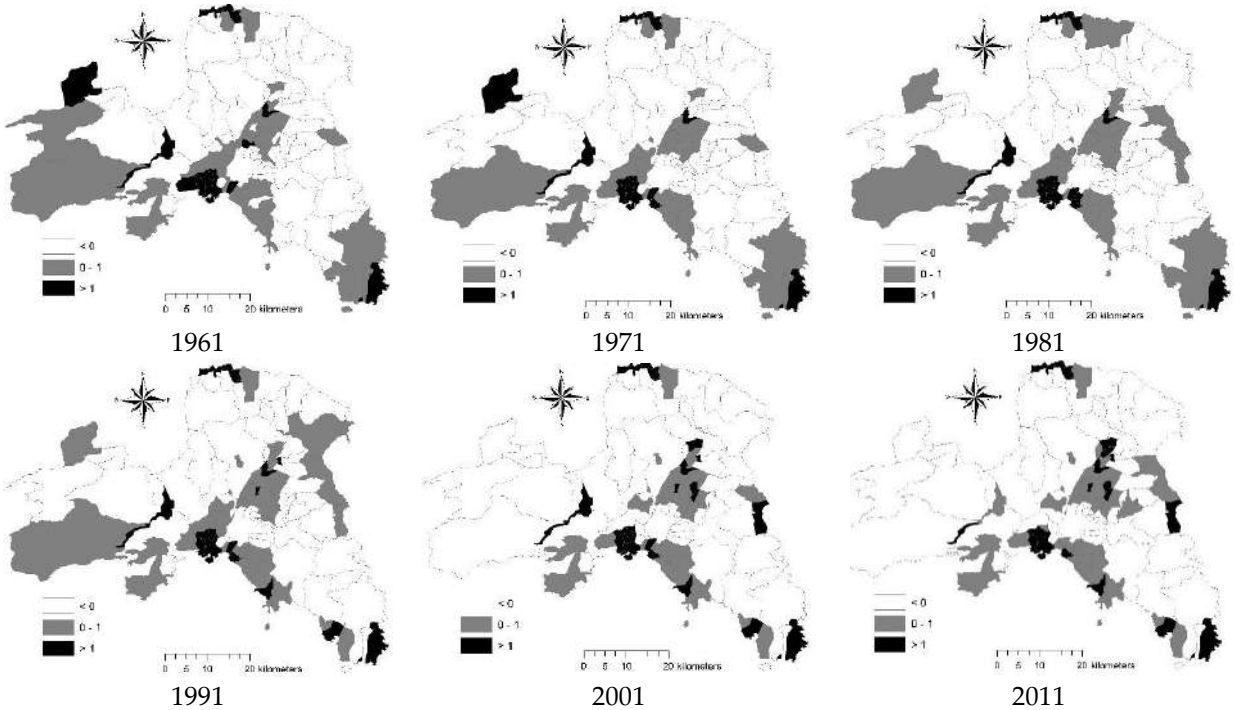
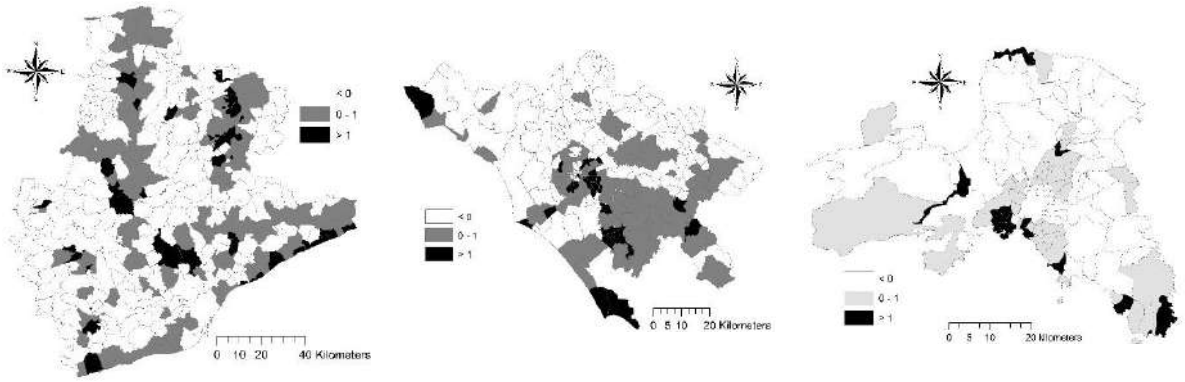


Figure 3.37. Spatial distribution of the standardized residuals from a regression model by year in Athens.

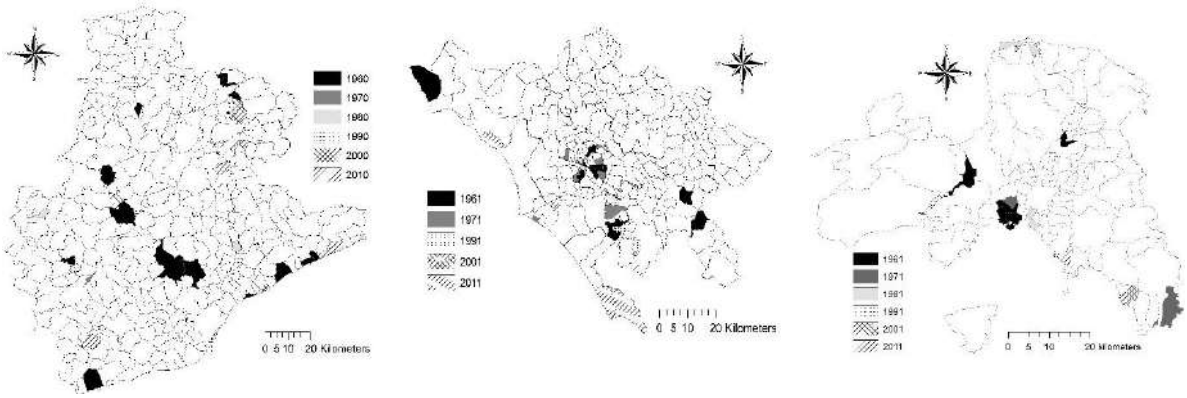


Barcelona Rome Athens

Figure 3.38. Maps of the average standardized residuals from a regression model for each municipality over the study period by city.

3.9.4. Local-scale trajectories based on residuals of a density-distance regression model

A summary outline of recent trajectories of urban growth in the three cities was derived from a map, as shown in Figure 3.39, illustrating the year when the highest standardized residual from a density-distance model was observed for each candidate municipality (i.e., with average standardized residuals >1). In Barcelona, coastal municipalities and municipalities along the highway to Zaragoza received the highest positive residuals at the first observation year (1960). Some internal municipalities in the outer ring of Barcelona and along the highway to the Pyrenees mountains received particularly high residuals in more recent time periods, possibly indicating urban fragmentation and a local development oriented toward consolidation of specific urban nodes in recent decades. In Rome, outer ring districts, inland municipalities, and a coastal municipality (Civitavecchia) received the highest residuals in 1961 or 1971. Municipalities with the highest residuals observed in the most recent time are situated along the coastal sea line (Anzio, Ladispoli). Municipalities belonging to the Greater Athens area received the highest residuals in 1961. Municipalities assuming the highest positive residuals in recent decades are more scattered over space and most of them are situated along the sea coast. In all cases, peri-urban locations identified as candidate sub-centers received the highest residuals in the first decades of the time interval; rural locations—or locations more distant from central cities—identified as candidate sub-centers, showed the highest residuals in more recent decades (2001 or 2011).



Barcelona Rome Athens

Figure 3.39. Maps indicating the year with the highest standardized residual from a density-distance model for each municipality by city.

3.9.5. Exploring urbanization processes and identifying polycentric development

Regional science is oriented toward multidisciplinary approaches exploring urbanization processes and identifying polycentric development according to concepts of metropolitan sustainability and regional resilience (Rontos et al., 2016; Serra et al., 2014; Zitti et al., 2015). A comprehensive analysis of polycentric processes of urban expansion requires setting up measures and criteria to define sub-centers considering population, employment, and/or economic activities. A comprehensive analysis of the spatial distribution of population over a sufficiently long time period may contribute to identification of spatial intensity and direction of polycentric growth (Duvernoy et al., 2018; **Pili** et al., **2017;** Díaz-Pacheco et al., 2014). In this regard, a comparative analysis of urban expansion is appropriate to define processes of spatial re-organization of metropolitan regions with the formation (and/or consolidation) of population sub-centers around the central city (Ward, 2008). A spatially-explicit, diachronic analysis of sub-central locations in metropolitan regions advances understanding of non-linear processes of urban growth and the underlying transformation of socioeconomic structures (Ward, 2008; Ward, 2010; Kourliouros, 1997).

The approach proposed here defines an operational framework that identifies population sub-centers using local analysis' spatial domains (e.g., municipalities, economic districts, homogeneous areas) under specific assumptions and criteria. Such analysis assumed that a polycentric structure is characterized by (more or less) considerable deviation from a linear model assessing urban typical relationships oriented along urban gradients, under the hypothesis that a classical mono-centric urban structure is satisfactorily described by a linear relationship between the two variables. Considering a relatively long time period, spatial units assuming systematically high residuals from a linear model linking population density with distance from the inner city are considered relevant examples of population sub-centers. Given the complex interactions between population dynamics and socioeconomic contexts reflected in specific spatial structures (Díaz-Pacheco et al., 2014).

The analysis of long-term urban transitions in three southern European cities (Athens, Rome, and Barcelona) was advanced, highlighting individual trajectories of metropolitan expansion. The three cities have experienced different urbanization waves influencing the overall metropolitan configuration, with variable impact on the original mono-centric structure.

In line with the empirical evidence of earlier studies, a variable number of candidate sub-centers was identified in the three cities, with a (more or less) scattered distribution along the urban gradient. Such growth trajectories are reflected in a specific spatial distribution of sub-centers. In the first decades of the study period, population sub-centers were identified more frequently in the outer ring of the three central cities. In the most recent decades, municipalities classified as sub-centers were situated at increasing distances from central cities, following the progressive expansion of metropolitan regions with moderate population de-concentration (Longhi and Musolesi, 2007; Maloutas, 2007; Turok and Mykhnenko, 2007). More specifically, population sub-centers identified in this study include (i) peri-urban municipalities around the central city and more remote towns situated in rural districts (Barcelona); (ii) scattered towns at variable distances (20-30 km) from the central city (Rome); (iii) fringe municipalities and peri-urban locations in flat districts, 10-20 km away from the central city (Athens). Such findings may indicate a distinctive evolution path toward polycentric development in the three cities, more evident in Barcelona and Rome and less evident in Athens.

These trajectories reflect two main urbanization phases with sequential waves of dense and dispersed urban growth over the last 50 years in Mediterranean Europe, the former being associated with compact, mono-centric expansion of central cities (1950-1980), the latter being characterized by a dispersed expansion of residential and service settlements into rural areas (1980-2010). In other words, the studied cities expanded through similar spatial patterns up to the early 1980s. In the following decades, urban expansion has produced differentiated morphologies and a (more or less) fragmented spatial organization of the three metropolitan regions (Salvati, 2013). Landscape morphology, the historic distribution of settlements and communication ways, land availability for building, and improved accessibility may justify such differences.

A comparative analysis of the three cities suggests that place-specific development models reflect a divergent spatial organization that may alter significantly the (presumed) homogeneity of forms and functions in Mediterranean cities (Zambon et al., 2017a; Salvati et al., 2015a). In line with this assumption, the empirical results obtained indicate that Barcelona's province is a moderately polycentric region. Municipalities classified as population sub-centers grew in number at progressively larger distances from the core city. The resulting urban structure shows a moderate balance of socioeconomic functions. By contrast, population re-distribution in Rome has partly modified the traditional spatial structure characterized by discontinuous and fragmented settlements organized in few towns around a compact city (De Muro et al., 2011). While being highly dispersed, this settlement structure was considered only moderately polycentric. The evolution of Athens' spatial structure is structurally different from paths observed in the other two cities. The organization of the metropolitan region at the beginning of the study period was basically mono-centric. Population and upper socioeconomic functions are concentrated in downtown Athens. Rapid urban expansion has reduced the demographic weight of both cities, consolidating sparse sub-centers along the urban fringe (Leontidou, 1990). Sub-centers have expanded over time at limited distances from the core city, simply merging morphologically-distinct settlements. This has prevented the creation of a (more or less) autonomous network of urban poles (Turok and Mykhnenko, 2007; Ceccarelli et al., 2014; Ferrara et al., 2014).

Decentralized, dispersed, and spatially unbalanced development in Mediterranean Europe has often led to social inequalities and economic polarization (Leontidou, 1996; Leontidou, 1995; Carlucci et al., 2017; Schwarz, 2010). Identification of new polycentric-oriented developmental patterns contributes to define multi-scale policies promoting a more cohesive regional growth that integrates urban competitiveness and sustainability targets (Corona et al., 2014; Getimis, 2012; Marchetti et al., 2015). A more comprehensive knowledge of long-term regional development paths may inform effective policies aimed at promoting polycentric development and regional competitiveness (Duvernoy et al., 2018; Pili et al., 2017). In this regard, policy makers and urban planners are increasingly required to integrate targets of economic competitiveness and socio-ecological sustainability in spatial policies envisioning more interconnected and less fragmented cities (Faludi, 2005). With the recent expansion of suburban areas (Garcia-López, 2012), planning systems in southern Europe could rethink urban models towards more sustainable and equilibrated regional forms (Salvati and Carlucci, 2016), e.g., taking into consideration zero-net land consumption targets (Salvati, 2014a; Zambon et al., 2017a) and urban containment measures (Couch et al., 2007).

Polycentric development has transformed traditional, mono-centric Mediterranean cities (Salvati and De Rosa, 2014; Schneider and Woodcock, 2008; Hall, 2009). This new regional structure should be investigated through spatially explicit, diachronic, and comparative approaches (Colantoni et al., 2015; De Rosa and Salvati, 2016; Ioannidis et al., 2009; Morelli et al., 2014). The originality of this study consists in the use of basic census data and generalized criteria defining population sub-centers. The proposed methodology can be generalized and adapted, for example, to discriminate population from employment sub-centers in metropolitan regions all over Europe. In this regard, a refined statistical approach could be implemented using multi-domain socioeconomic indicators and spatially-explicit analysis techniques together (including spatial statistics and geographic information systems modeling). The integration of exploratory and inferential data analysis can overcome the inherent difficulty when investigating Mediterranean urban gradients, contributing to define peculiar socio-economic contexts.

3.10. In between economic development and crisis

Demographic dynamics in Europe have evolved continuously over time and space, reflecting specific socioeconomic contexts and cultural variety of individual countries (Beetz 2013; Van Nimwegen 2013; Leibert and Golinski 2017). Demographic Transitions (DTs) in modern industrial societies have been intended as 'a pathway to change' (Lee and Reher 2011) since lifespan became longer, with a progressive decline in mortality and fertility rates and heterogeneous rates of population growth (Lee 2003; Clark and Alter 2010; Blue and Espenshade 2011). With DTs, intimate transformations of societies and economic systems gave rise to a period of growth and prosperity that has characterized the modern era for a long time (Khan 2008). DTs have resulted in developmental processes influencing urban configurations and altering the distribution of economic functions at the metropolitan scale (Walford and Kurek 2016). The effect of social interactions has been also considered in theoretical approaches to fertility decline in both emerging countries and in some European countries (Watkins 1990; Montgomery and Casterline 1996; Behrman et al., 2002).

Empirical studies have more recently attempted to explain the intrinsic relationship between demographic changes and economic cycles (Khan 2008; Goldstein et al., 2013; Simou et al., 2013). The Second Demographic Transition (SDT) has coincided with important social transformations and extensive processes of population redistribution at regional scale (Lesthaeghe and van de Kaa 1986; van de Kaa 1987). Heterogeneous population dynamics resulting from the SDT, have delineated a new kind of (smaller) households, individual decisions to marriage and cohabitation, a progressive decline in fertility, a delay in child-bearing and a generalized population aging (Billari and Kohler 2004; Haase et al., 2010). Spatially-varying population dynamics represent one of the main outcomes of differential mechanisms of demographic transitions at the country scale, possibly depending on distinct social contexts, economic structures and performances (Van Bavel and Reher 2013). Such dynamics gave rise to new territorial structures in several European countries (Lesthaeghe and Surkyn 2002; Caldwell and Schindlmayr 2003; Sobotka 2003; Liu 2005; Kalmijn and van Tubergen 2006; Rontos 2007; Sobotka and Toulemon 2008; Goldstein et al., 2009; Coleman 2013; Sobotka 2013).

Cited article

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In Southern Europe, the SDT has manifested with negative population growth rates and low fertility levels prevailing during the 1990s (Rontos 2010), being also influenced by migratory flows (Blangiardo and Rimoldi 2012). At the same time, suburbanization processes have shaped the spatial distribution and structure of population across metropolitan regions (Grigoriadis and Salvati 2015). As a matter of fact, recent demographic patterns have altered the traditional density gap between urban and rural areas, influencing the hierarchy of large- and medium-size cities and local socioeconomic systems (van Criekingen 2010). A thorough assessment of the (increasing) demographic divides along urban-rural gradients requires an empirical approach focusing on a comparative analysis of changes in the spatial distribution of population along economic cycles (Haase et al., 2010; van Criekingen 2010; Kroll and Kabisch 2012). The 2007 crisis has finally made the demographic dynamics along urban-to-rural gradients even more complicated, consolidating in

some cases social segregation and a traditionally polarized distribution of economic activities (Sobotka et al., 2011).

Economic cycles have affected considerably the size, composition and distribution of European population (Van Nimwegen 2013). Fertility fluctuations are contingent under crisis' pressure because of unemployment, job instability and a generalized postponement of new families' formation (Adsera 2004; Billari and Kohler 2004; Simou et al., 2013). Recessionary shocks can be thus considered a factor altering spatial and temporal dynamics of population (Goldstein et al., 2013), and require a comprehensive assessment based on the integrated analysis of demographic indicators over time and space (Simou et al., 2013).

Identifying and characterizing demographic changes in Greece, separately for a long-time period (1961-2007) and a subsequent, shorter time interval (2008-2015) have the purpose to verify if the impact of 2007 recession on short-term demographic dynamics has been neutral compared with background, long-term trends. Greece, one of the European countries most affected by crisis (Goldstein et al., 2013; Simou et al., 2013; Goldstein and Kluge 2016), was selected as a representative context for studying the influence of economic cycles on both long- and short-term changes in population dynamics (Gkartzios and Scott 2015; Grigoriadis and Salvati 2015; Remoundou et al., 2015). Basic indicators were used to identify similarities and differences in demographic trends before and during the 2007 crisis, comparing regional-scale dynamics for the whole of Greece and Attica, the densest metropolitan region hosting Athens, the Greek capital.

3.10.1. A multidimensional approach for long-term and short-term changes

This study focuses on two spatial partitions: (i) the whole of Greece and (ii) the administrative region of Attica including the metropolitan region of Athens, with a population density ranging from nearly 100 inhabitants/km^2 in the whole of Greece to 3,000 inhabitants/km^2 of Attica (Salvati et al., 2015a). Population dynamics in Greece have been taken as representative of more general demographic trends typical of urban-rural gradients in southern Europe since the late 1950s, influencing urbanization cycles (Woods 2005; Kasimis 2008; Chorianopoulos et al., 2010). In the 1960s, rural-urban migration occurred in metropolitan regions, given the concentration of economic activities (Damianakos 2002; Maloutas 2007; Gkartzios 2013). While in the 1970s internal migration fueled urban expansion in Greece as well as in other southern European countries, migration flows in the 1980s were directed mostly to peri-urban areas, in parallel with a stagnant population growth in city cores (Rontos 1987; Kotzamanis 1997; Sayas 2006).

Urban population consolidated in the 1990s thanks to immigration from neighbouring countries, despite a low birth rate of native population. Mean age of women at marriage and childbearing in Greece has exceeded 30 years (Rontos 2007). Without the contribution of foreign migrants during the 1990s and the 2000s, Greece would have experienced the lowest fertility rate of the pre-crisis period (Goldstein et al., 2009). However, increasing incomes and high birth rates in this period have reflected better living conditions of resident population in some urban areas (Rontos 2010; Santow and Bracher 2011; Sobotka et al., 2011). Since the mid-1990s, Attica has attracted public and private investments to keep up suburban growth (Delladetsima 2006). The most recent Olympics (2004) have stimulated urban expansion with development of new infrastructures (Chorianopoulos et al., 2014). The 2007 recession finally resulted in a discontinuous urban growth, high unemployment, volatile job markets and moderate changes in population structure (Goldstein et al., 2013;

Grigoriadis and Salvati 2015; Rontos et al., 2016). With economic crisis, unemployment rates have increased rapidly, and incomes dropped consequently (Simou et al., 2013).

Population data considered in this study are based on vital statistics (marriages, births and deaths) released yearly by Hellenic Statistical Authority (ELSTAT) for the whole of Greece and for each administrative region of the country. Based on the available time series, a preliminary assessment of Greek demographic trends was carried out analysing basic indicators including (i) population density (inhabitants/km^2, hereafter 'POP'); (ii) crude rate (births/deaths) of natural increase ('CRU'); (iii) natural increase per 100 inhabitants ('NAT'); (iv) births per marriage ('BRM'); (v) births per 100 inhabitants ('BRI'); (vi) marriages per 1000 inhabitants ('MAR'); and (vii) deaths per 100 inhabitants ('DEA'). These indicators have been continuously recorded over the study period (1961-2015) and may provide a comprehensive picture of short-term and long-term demographic dynamics for both Attica and Greece. The most recent time frame (2000-2015) covers two separate phases: (i) economic expansion with dispersed urbanization (2000-2007) related to the 2004 Olympics in Athens; and the most recent crisis (2008-2015), characterized by austerity urbanism, rising socioeconomic disparities and poverty (Salvati and De Rosa 2014). Since Attica was (and is) the most dense and urbanized region in the country, a comparative analysis allows recognizing changes in the recent demographic history of Greece, outlining convergent (or divergent) population dynamics among urban and rural regions.

A Principal Component Analysis (PCA) was run with the aim to extract few relevant dimensions from a wide number of key indicators, obtaining a comprehensive outlook of spatio-temporal demographic patterns in Greece (Salvati et al., 2016c). PCA was developed using a data matrix composed of the selected indicators for each spatial unit and study year (Mazziotta and Pareto 2016). PCA basically (i) reduces redundancy among indicators, (ii) explores multiple correlations among population attributes and (iii) identifies latent variables that are useful to characterize external factors underlying short-term and long-term population dynamics (Ruther et al., 2013). Component loadings were used to illustrate changes over time in the input variables. Loadings allow an implicit ranking of indicators based on their contribution to short-term and long-term demographic dynamics in the study area (Lesthaeghe and Neidert 2006; Salvati and Sabbi 2014; Salvati and Serra 2016).

A two-way hierarchical clustering (based on Euclidean distance metric and Ward's agglomeration rule) was run on a data matrix composed of the active variables entering PCA by use of (Mazziotta and Pareto 2016). Cluster analysis provided data in a hierarchical sequence through a dendrogram, grouping years with similar demographic dynamics. A Regime Shift Analysis (RSA) was performed through a change point detection analysis with the aim to identify temporal shifts in the multivariate dataset (Sullivan and Woodall 2000). Probability ratio test statistics for a significant shift specified the time (i.e. years) at which relevant changes in the distribution of individual variables have occurred. A Stepwise Linear Discriminant Analysis (LDA) was finally applied on hierarchical clusters as a-priori groups separately for Attica and Greece. According to Wanner (1977), each observation was classified based on a pre-defined probability criterion (p-value < 0.0001) using the indicators with the highest discriminant power among clusters (Salvati and Sabbi 2014). Canonical plots revealed points (i.e. years) and multivariate means (i.e. clusters) in the most relevant dimensions extracted (Salvati et al., 2015b).

3.10.2. Statistics and demographic responses to recession

Recent demographic history of Greece and Attica was described using seven indicators made available along a consistent time interval (1961-2015). The spatial gap in population density between Attica and Greece increased over time (Table 3.27). Population density in Attica increased from 540 to 1003 inhabitants/km^2 during the time interval considered in this study. Comparing absolute figures, Attica concentrated respectively 476 and 921 inhabitants/km^2 in 1961 and 2015 more than Greece, with a peak value of 974 inhabitants/km^2 in 2007.

'CRU' and 'NAT' indicators decreased considerably over time (Table 3.28). Natural population increase was systematically higher in Attica than in Greece since 1971, being negative for Greece (deaths > births). The 'NAT' indicator showed a negative trend overall (Figure 3.40); however, a peak (2005-2007) and a subsequent decline observed since 2011 for both Attica and the whole of Greece, were considered representative of the 2007 crisis' impact on regional demographic dynamics. Births per marriage were growing slightly over time in both Attica and Greece, being higher in Greece than in Attica. The absolute rate of change increased over time from -0.25 to 0.05 for births per 100 inhabitants. Marriages per 1000 inhabitants have decreased quickly since 1961 (from 9.84 to 4.90 in the case of Attica). Marriage rate was higher in Attica than in the whole of Greece, even if absolute change rates outlined a reduction in the share of marriages celebrated in Attica in total Greek marriages. Slightly higher death rates were observed for the whole of Greece than for Attica, with the highest levels being recorded in the most recent years (Figure 3.41).

Table 3.27. Demographic indicators in Greece, 1961-2015.

Year	POP	CRU	NAT	BRM	BRI	MAR	DEA
1960	-	2.60	-	2.73	-	-	-
1961	64	2.36	1.03	2.15	1.80	8.34	0.76
1965	-	2.26	-	1.90	-	-	-
1970	-	1.96	-	2.19	-	-	-
1971	66	1.92	0.77	1.95	1.61	8.23	0.84
1975	-	1.78	-	1.89	-	-	-
1980	-	1.70	-	2.40	-	-	-
1981	74	1.64	0.56	2.00	1.45	7.23	0.88
1982	74	1.60	0.52	2.04	1.40	6.86	0.88
1983	75	1.47	0.43	1.88	1.35	7.16	0.92
1984	75	1.43	0.38	2.32	1.27	5.47	0.89
1985	75	1.26	0.24	1.85	1.17	6.34	0.93
1986	76	1.23	0.21	1.96	1.13	5.76	0.92
1987	76	1.12	0.11	1.63	1.06	6.53	0.95
1988	76	1.17	0.15	2.28	1.07	4.69	0.92
1989	76	1.10	0.09	1.66	1.01	6.05	0.91
1990	77	1.09	0.08	1.76	1.00	5.72	0.92
1991	77	1.08	0.07	1.59	1.01	6.31	0.93
1992	78	1.06	0.06	2.19	1.01	4.60	0.95
1993	79	1.05	0.04	1.66	0.97	5.85	0.93
1994	80	1.06	0.06	1.86	0.98	5.29	0.92
1995	80	1.01	0.01	1.61	0.95	5.92	0.94
1996	81	1.00	0.00	2.27	0.94	4.14	0.94
1997	81	1.02	0.02	1.72	0.94	5.50	0.92
1998	82	0.98	-0.02	1.86	0.93	5.00	0.94
1999	82	0.97	-0.02	1.68	0.92	5.48	0.95
2000	83	0.98	-0.02	2.18	0.94	4.32	0.96
2001	83	1.00	0.00	1.81	0.93	5.16	0.93
2002	83	1.00	0.00	1.86	0.94	5.06	0.94

2003	83	0.99	-0.01	1.77	0.95	5.34	0.95
2004	84	1.01	0.01	2.15	0.96	4.44	0.95
2005	84	1.03	0.02	1.85	0.97	5.24	0.94
2006	84	1.06	0.06	2.05	1.00	4.90	0.94
2007	85	1.02	0.02	1.92	1.00	5.21	0.98
2008	84	1.10	0.09	2.34	1.06	4.55	0.97
2009	84	1.09	0.09	2.09	1.06	5.05	0.97
2010	84	1.06	0.05	2.16	1.03	4.78	0.97
2011	84	0.96	-0.04	2.05	0.96	4.67	1.00
2012	83	0.86	-0.14	2.17	0.91	4.19	1.05
2013	83	0.85	-0.16	1.98	0.86	4.33	1.02
2014	82	0.81	-0.19	1.90	0.85	4.45	1.04
2015	82	0.76	-0.27	1.88	0.85	4.51	1.12

Table 3.28. Demographic indicators in Attica, 1961-2015.

Year	POP	CRU	NAT	BRM	BRI	MAR	DEA
1960	-	2.34	-	2.18	-	-	-
1961	540	2.16	0.83	1.57	1.54	9.84	0.72
1965	-	2.29	-	1.61	-	-	-
1970	-	2.23	-	1.95	-	-	-
1971	735	2.19	0.90	1.71	1.66	9.71	0.76
1975	-	2.15	-	1.71	-	-	-
1980	-	2.10	-	2.43	-	-	-
1981	885	1.95	0.74	1.86	1.52	8.18	0.78
1982	890	1.90	0.69	1.93	1.47	7.61	0.77
1983	896	1.78	0.61	1.74	1.40	8.05	0.79
1984	901	1.65	0.51	2.25	1.29	5.75	0.78
1985	904	1.43	0.36	1.71	1.19	6.99	0.84
1986	908	1.40	0.33	1.84	1.14	6.19	0.81
1987	911	1.19	0.17	1.44	1.06	7.31	0.89
1988	915	1.28	0.23	2.17	1.06	4.89	0.83
1989	923	1.22	0.18	1.50	1.01	6.72	0.82
1990	926	1.20	0.17	1.60	1.02	6.39	0.85
1991	941	1.23	0.19	1.44	1.02	7.09	0.83
1992	953	1.20	0.17	2.14	1.02	4.78	0.85
1993	962	1.15	0.13	1.52	0.98	6.43	0.85
1994	972	1.18	0.15	1.73	0.98	5.67	0.83
1995	981	1.12	0.11	1.48	0.96	6.48	0.85
1996	990	1.10	0.09	2.19	0.94	4.28	0.85
1997	998	1.11	0.10	1.58	0.95	5.97	0.85
1998	1006	1.07	0.06	1.70	0.93	5.49	0.87
1999	1013	1.07	0.06	1.57	0.93	5.95	0.87
2000	1018	1.08	0.07	2.06	0.95	4.62	0.88
2001	1022	1.12	0.10	1.70	0.95	5.60	0.85
2002	1025	1.12	0.10	1.77	0.96	5.42	0.86
2003	1028	1.13	0.11	1.68	0.98	5.83	0.87
2004	1035	1.14	0.12	2.11	0.99	4.68	0.87
2005	1043	1.14	0.12	1.71	0.99	5.75	0.86
2006	1051	1.21	0.17	1.95	1.02	5.23	0.85
2007	1059	1.15	0.13	1.80	1.02	5.67	0.89
2008	1050	1.23	0.20	2.26	1.07	4.74	0.87
2009	1051	1.21	0.18	1.99	1.07	5.37	0.89
2010	1049	1.18	0.16	2.05	1.05	5.12	0.89
2011	1041	1.08	0.08	2.00	1.00	4.99	0.92
2012	1028	0.98	-0.02	2.18	0.95	4.37	0.97
2013	1015	0.94	-0.06	1.93	0.90	4.65	0.95

2014	1004	0.92	-0.08	1.86	0.90	4.84	0.98
2015	1003	0.85	-0.16	1.83	0.90	4.90	1.05

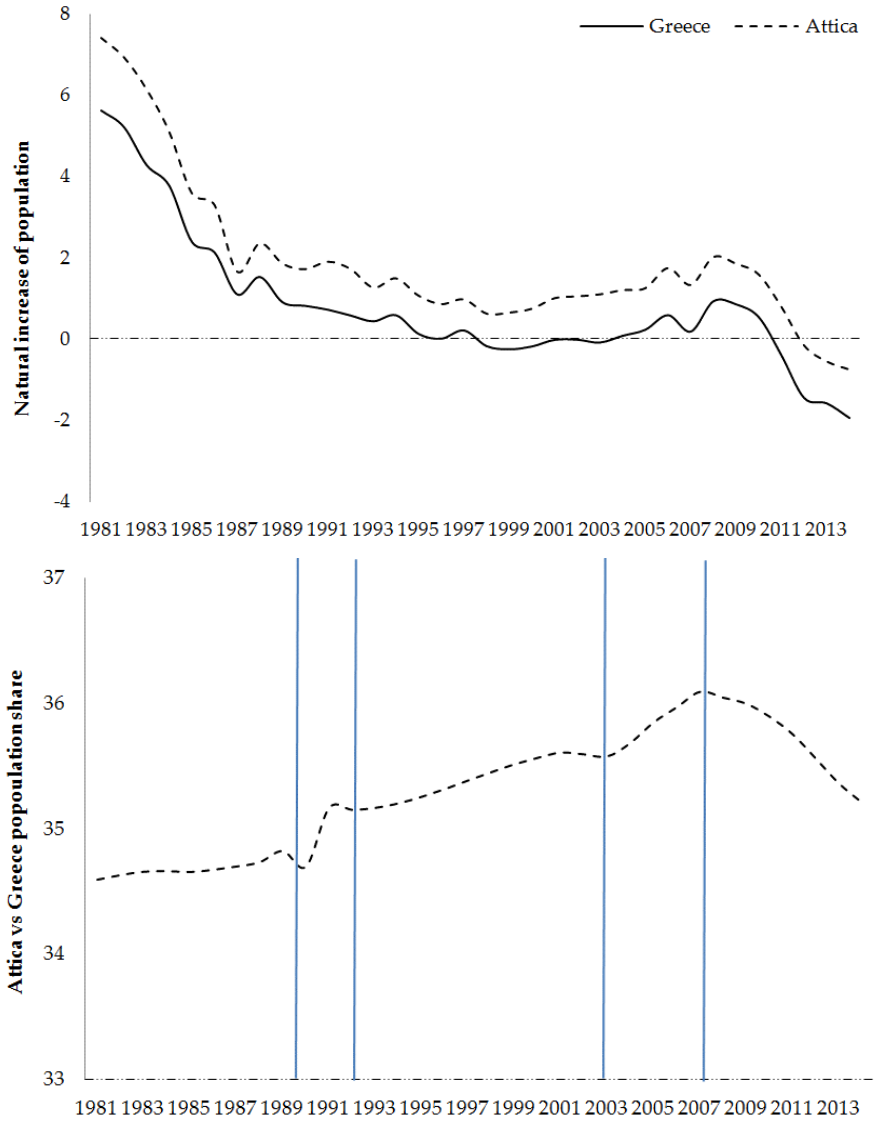


Figure 3.40. Natural increase of population in Attica and Greece (upper graph) and share of Attica's population in Greek population.

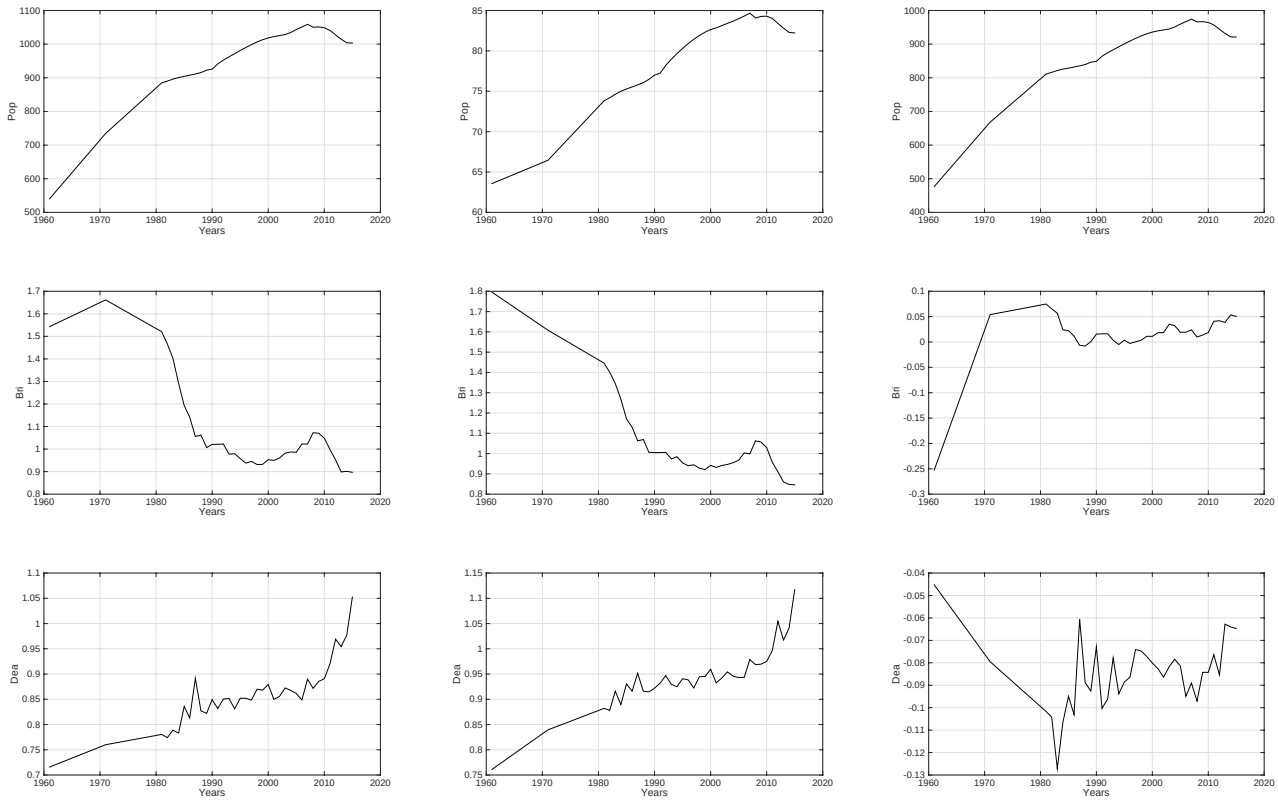
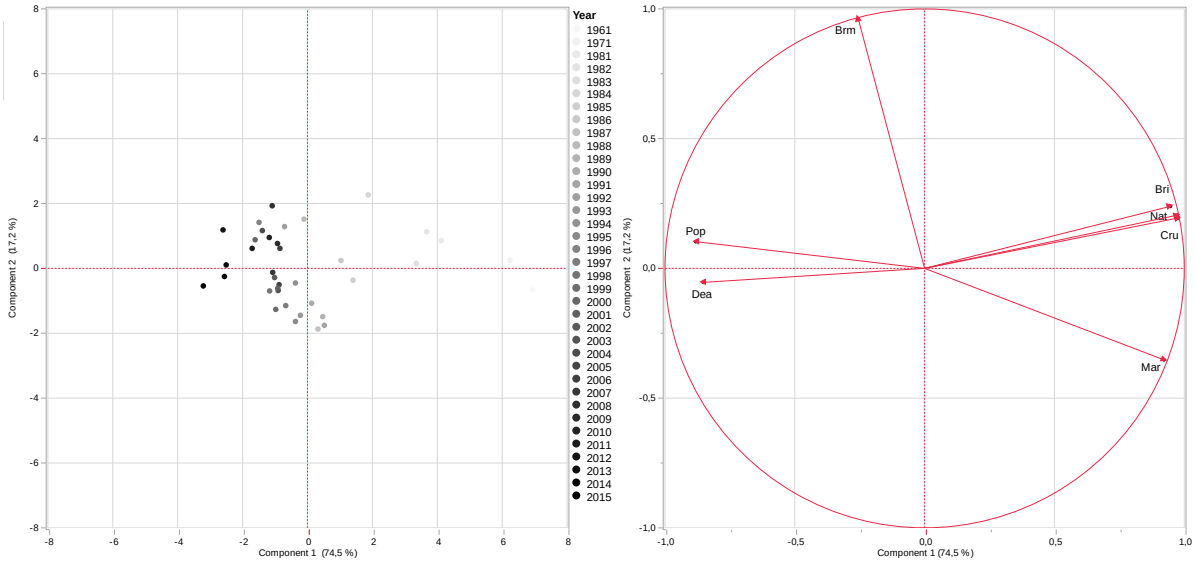


Figure 3.41. Time series of POP, BRI and DEA variables, respectively for Attica (left panel), Greece (central panel) and absolute differences between Greece and Attica (right panel).

PCA extracted nearly 90% of the total variance concentrated in the first two axes. PCA scores for Attica and Greece were reported respectively in the upper and lower parts of Figure 3.42. Different colours illustrate years from 1961 (lightest grey) to 2015 (black). A PCA loading plot was reported in the right side. Indicators of population structure received the highest value on the first component (PC1) for both Attica and the whole of Greece. PC2 was correlated with population density, births per marriage and per 100 inhabitants for both spatial partitions.



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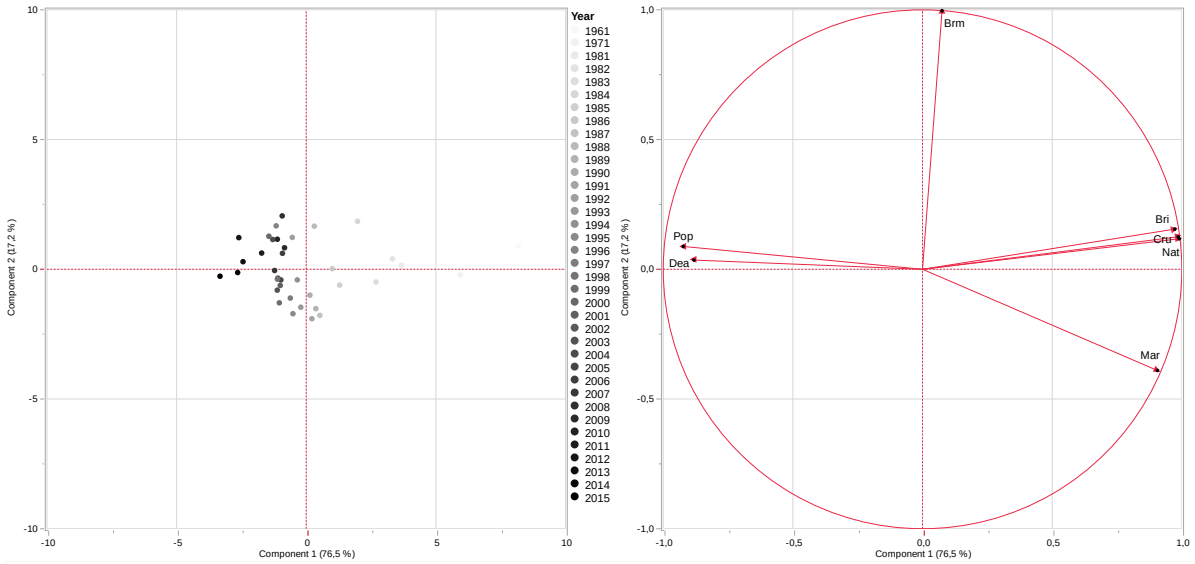

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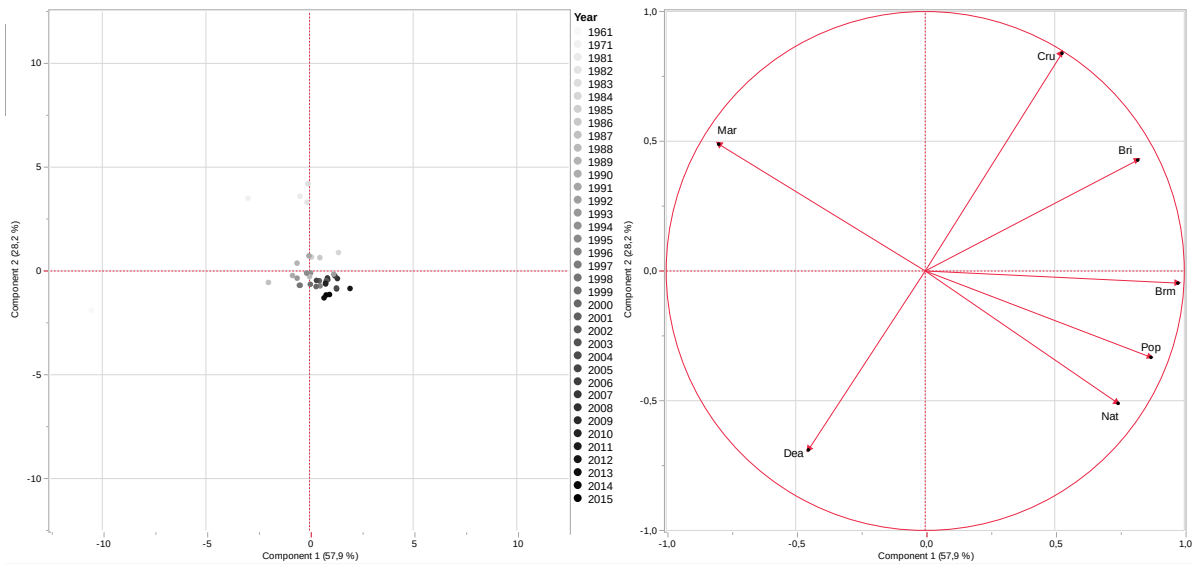


Figure 3.42. PCA score and loading plot for Attica (top), Greece (center) and absolute difference between the two spatial domains (bottom); grey ramp indicates the studies years, from soft grey (1961) to black (2015).

Hierarchical clustering (Figure 3.43) identified three-time intervals with homogeneous demographic dynamics (1961-1986, 1987-2007 and 2008-2015). The first time period was characterized by increasing population density, low death rates per 1000 inhabitants and high birth rates per marriage. The second time period was characterized by high crude rate of natural increase and natural increase per 100 inhabitants, high rates of births per 100 inhabitants and marriages per 1000 inhabitants. These findings are consistent with the results presented in section 3.2 and indicate that population transitions in Attica and the whole of Greece can be distinguished considering changes over time in basic indicators of population structure and dynamics.

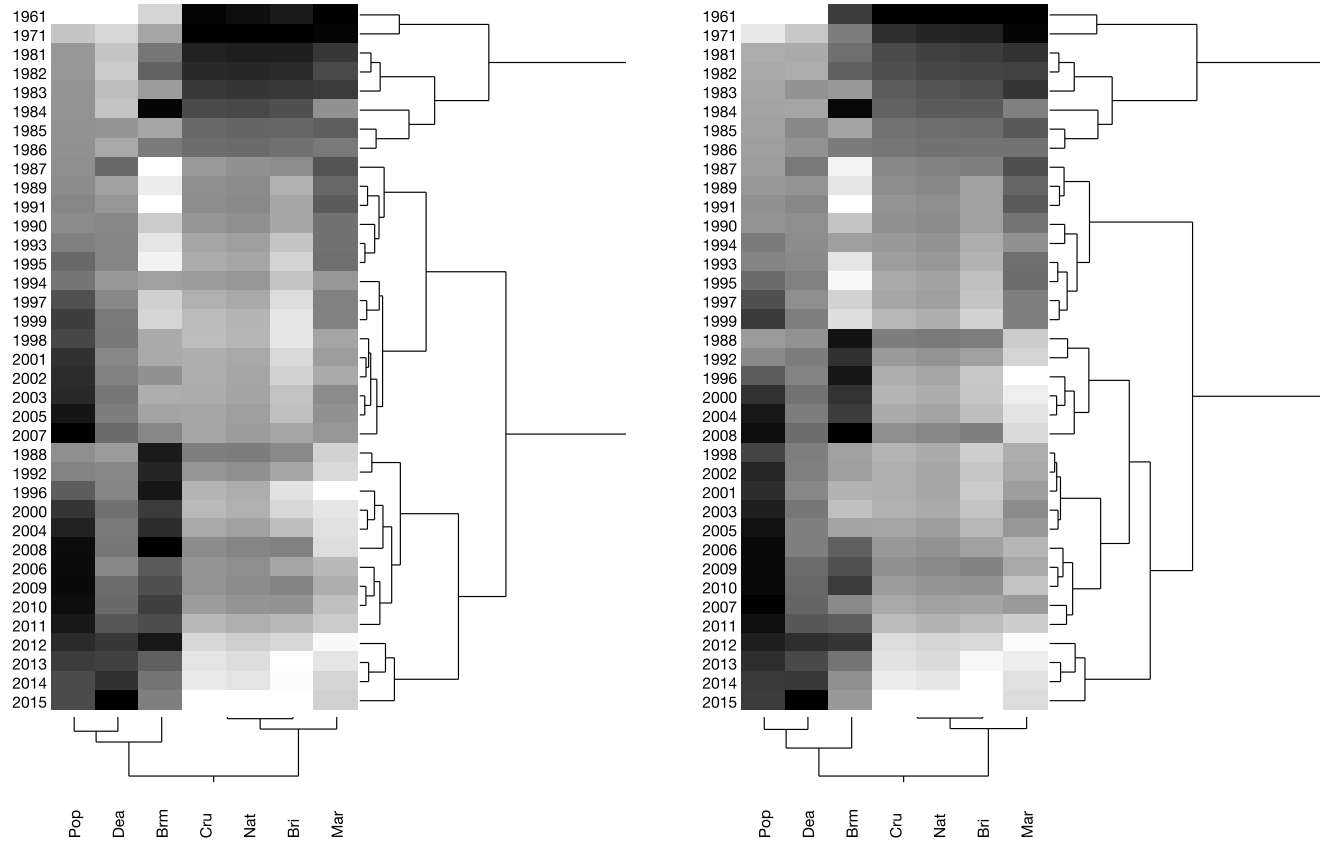


Figure 3.43. Two-way hierarchical clustering of population dynamics in the Attica region (left) and Greece as a whole (right).

To explore shifts in regional demographic regimes during the study period, a Regime Shift Analysis (RSA) was run separately for each indicator and for the whole dataset considered in this study, with the objective to detect break points in the individual time series and to study spatial variability in the multivariate set of demographic indicators. The most significant point in time at which a change in demographic characteristics was detected is 1986 (Table 3.29). Such findings are in line with the results presented in sections 3.2 and 3.3. However, the contribution of each indicator in determining the 1986 (and other) break-point(s) in the overall data matrix was quite differentiated. Population density increased with a breaking point corresponding to the years 1995-1996. Conversely, a strong decline in marriage rate was recorded for Attica region in 1991 and 4 years later (1995) for the whole of Greece.

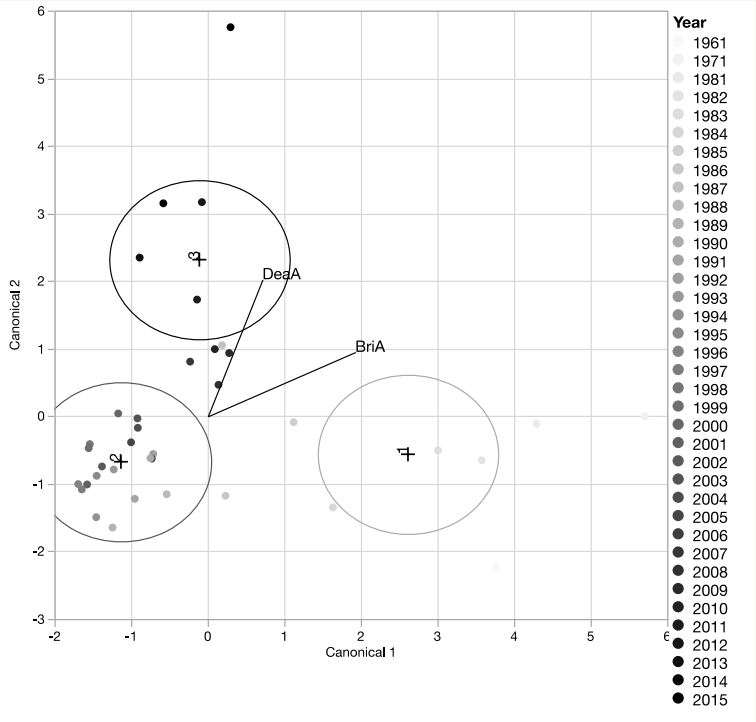
Table 3.29. Absolute difference in selected demographic indicators between Attica and Greece (Greece-Attica), 1961-2015.

Year	POP	CRU	NAT	BRM	BRI	MAR	DEA
1960	-	-0.26	-	-0.55	-	-	-
1961	476	-0.20	-0.21	-0.58	-0.25	1.50	-0.05
1965	-	0.03	-	-0.29	-	-	-
1970	-	0.27	-	-0.24	-	-	-
1971	668	0.27	0.13	-0.24	0.05	1.48	-0.08
1975	-	0.36	-	-0.18	-	-	-
1980	-	0.40	-	0.03	-	-	-
1981	811	0.31	0.18	-0.14	0.07	0.96	-0.10
1982	816	0.30	0.17	-0.12	0.07	0.75	-0.10
1983	822	0.31	0.18	-0.14	0.06	0.89	-0.13

1984	826	0.22	1.31	-0.07	0.02	0.28	-0.11
1985	829	0.17	1.18	-0.14	0.02	0.65	-0.09
1986	832	0.17	1.15	-0.12	0.01	0.43	-0.10
1987	835	0.07	0.54	-0.18	-0.01	0.78	-0.06
1988	839	0.12	0.81	-0.11	-0.01	0.19	-0.09
1989	846	0.12	0.93	-0.17	0.00	0.67	-0.09
1990	849	0.11	0.89	-0.16	0.02	0.67	-0.07
1991	864	0.15	1.16	-0.15	0.02	0.78	-0.10
1992	874	0.14	1.12	-0.05	0.02	0.19	-0.10
1993	883	0.10	0.81	-0.14	0.00	0.58	-0.08
1994	892	0.11	0.89	-0.13	0.00	0.38	-0.09
1995	901	0.11	0.92	-0.13	0.00	0.56	-0.09
1996	909	0.10	0.84	-0.08	0.00	0.14	-0.09
1997	917	0.09	0.74	-0.14	0.00	0.47	-0.07
1998	924	0.09	0.78	-0.16	0.00	0.49	-0.07
1999	931	0.10	0.88	-0.11	0.01	0.47	-0.08
2000	936	0.10	0.91	-0.12	0.01	0.31	-0.08
2001	939	0.12	1.01	-0.11	0.02	0.44	-0.08
2002	942	0.12	1.05	-0.09	0.02	0.36	-0.09
2003	945	0.13	1.17	-0.09	0.04	0.49	-0.08
2004	951	0.13	1.11	-0.04	0.03	0.25	-0.08
2005	959	0.12	1.01	-0.13	0.02	0.51	-0.08
2006	967	0.14	1.14	-0.09	0.02	0.33	-0.09
2007	974	0.13	1.13	-0.12	0.02	0.47	-0.09
2008	966	0.13	1.07	-0.07	0.01	0.19	-0.10
2009	967	0.12	0.98	-0.10	0.01	0.32	-0.08
2010	964	0.12	1.03	-0.11	0.02	0.34	-0.08
2011	957	0.12	1.17	-0.05	0.04	0.32	-0.08
2012	944	0.12	1.27	0.01	0.04	0.18	-0.09
2013	932	0.10	1.01	-0.05	0.04	0.32	-0.06
2014	922	0.11	1.18	-0.04	0.05	0.39	-0.06
2015	921	0.09	1.11	-0.05	0.05	0.39	-0.06

A characteristic trend over time was also observed for death rates, with a recent breaking point in correspondence with the beginning of the most recent crisis. While mortality rate was rather constant in the years preceding the 2007 crisis, a significant change occurred since 2010. Increasing 'DEA' figures in recent years are related to the early impact of crisis on Greek population, causing a slow but continuous mortality rise.

Differences in the statistical distribution of demographic indicators were assessed using a step-wise Linear Discriminant Analysis (LDA) distinguishing three-time intervals (1961-1986, 1987-2007 and 2008-2015) identified by hierarchical clustering (section 3.3). Results of the LDA run on the 3 a-priori groups are reported in Figure 3.44 and Table 3.30 for each considered spatial partition. Canonical plots illustrate the dimensions that better segregate the groups identified by LDA. The highest discriminant power among clusters was assigned to crude rate of natural increase ('CRU'), births per 100 inhabitants ('BRI') and deaths per 100 inhabitants ('DEA'). Especially death rates revealed a peculiar trend over time at the regional level for Attica compared with the whole of Greece. However, results from the LDA have substantially confirmed that the selected indicators are key to understanding long-term and more recent demographic transitions at the regional scale in Greece.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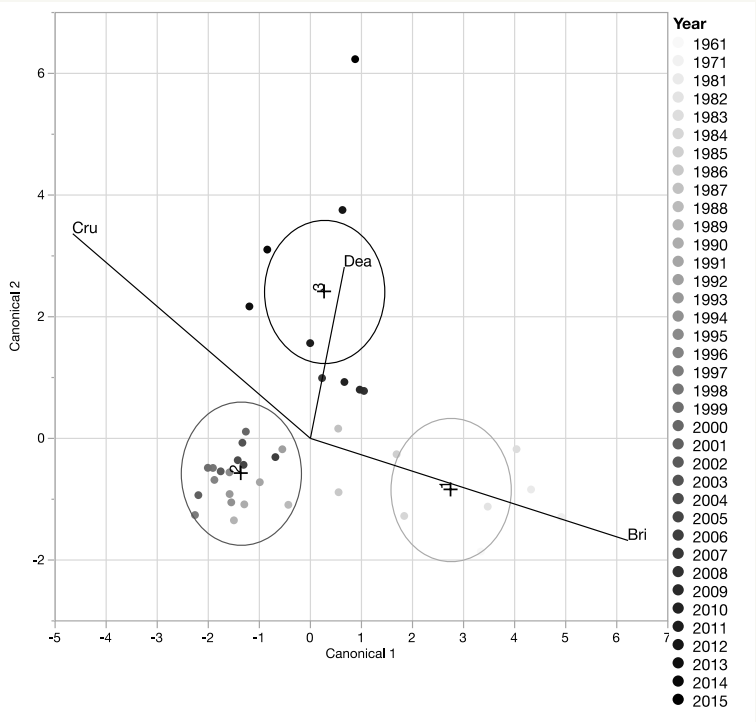
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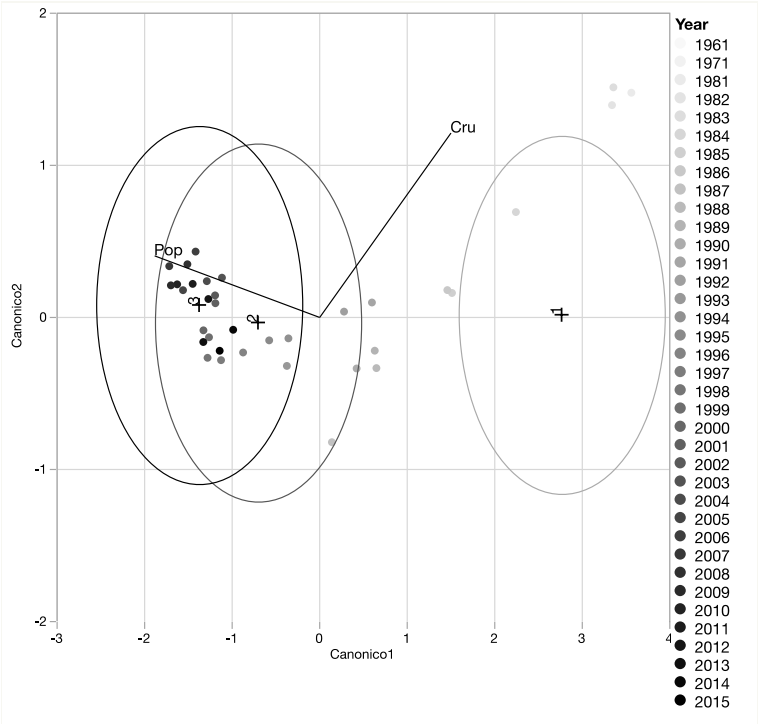

Figure 3.44. Canonical plots for the step-wise linear discriminant analysis relevant to the Attica region (left), Greece as a whole (middle) and the related, absolute difference between the two spatial partitions (right).

Table 3.30. Years at which a shift was observed in each indicator considered in this study, based on a change point detection analysis.

Indicator	Attica	Greece	Absolute Difference
POP	1995	1996	1995
CRU	1986	1986	1987
NAT	1986	1986	1983
BRM	-	-	1961
BRI	1986	1986	1983
MAR	1991	1995	1991
DEA	2010	2006	2012
All variable together	1995	1995	1991

Table 3.31. Results of a step-wise linear discriminant analysis results distinguishing population dynamics under pre-crisis (1961-2007) and crisis (2008-2015) periods.

Variable	Attica	Greece	Abs. Difference
BRI	38.4*	7.8*	
DEA	27.9*	15.6*	
CRU		3.9*	13.2*
POP			38.6*
% Corrected Classified	89.2	91.9	64.9
Wilks' Lambda	0.1	0.1	0.2
F	33.9	25.2	5.3
df	4.7	6.6	14.6

* p-value < 0.0001

3.10.3. Population dynamics in Greece and the impact of economic restrictions

The most recent financial crisis has attracted a strong interest on research issues dealing with economic instability and population/family changes (Neels et al., 2012). Earlier studies have

demonstrated how economic shocks are impacting significantly population structure, marriages' decisions, fertility and mortality trends (Watkins 1990; Proietti 2005; Rontos 2010). More recent studies have also highlighted the role of the state in the decision of planning new family and childbearing (Sobotka et al., 2011; Salvati et al., 2016c). Demographic indicators may provide an informative base to understanding linkages between population dynamics and evolving socioeconomic contexts (Matthews and Parker 2013; Johnson et al., 2015; Goldstein and Kluge 2016). The proposed approach, based on a restricted set of basic indicators, has compared long-term (1961-2007) and short-term (2008-2015) population dynamics, considering together the impact of economic cycles and societal transformations along urban-to-rural gradients. In this direction, the multivariate analysis performed pointed out a relevant demographic variability over time and space in Greece.

Although economic recession cannot be considered the unique driver of recent demographic dynamics - since many socioeconomic processes have combined and interact together (Kroll and Kabisch 2012; Goldstein et al., 2013). Empirical results of this study confirmed that demographic dynamics in Greece were highly sensitive to economic conditions. This evidence is in line with findings presented in earlier studies (Sobotka et al., 2011; Simou et al., 2013; Walford and Kurek 2016). During economic expansion, birth and marriage rates increased rapidly, especially in Attica, thanks to intense rural-urban migration (Arapoglou 2006). Migratory flows have proved to contribute to spatial demographic divides reflected in different rates of economic development among regions (Golini et al., 2014). Migration was recognized as a powerful factor of social transformations and economic growth in Attica (Lianos 2001; Rovolis and Tragaki 2006). Socioeconomic transition led to a progressive decline in fertility rate and changes in the 'traditional' families' structure (Buzar et al., 2007), being also a relevant factor of suburbanization, affecting e.g. land prices and local labor markets (Kroll and Kabisch 2012).

Despite a recovery in birth rates related to unemployment decline until 2007 (Remoundou et al., 2015), Greece has witnessed a reduction in fertility rate since 2008 (Sobotka et al., 2011). For instance, as stated by Goldstein et al., (2013), growth in fertility rates stopped in 2009, when Greek economy entered recession. Decline in marriage rates was mainly due to marriage postponement, more frequent in urban areas than in rural districts. In this ambit, economic crisis has impacted vulnerable social classes exposed to unemployment risk or receiving salaries below the poverty line (Gkartios and Scott 2015). Negative economic conditions have adversely affected new households' formation (Walford and Kurek 2016). These outcomes confirmed that socio-demographic polarization in urban and rural areas was exalted by the 2007 crisis, as earlier stated by Salvati et al., (2016b). Conversely, suburbanization assumed an important role in determining regional population dynamics in the pre-crisis period (Rontos et al., 2016).

Mortality rate has identified long-term and short-term demographic patterns in Greece better than other indicators. A break-point in mortality rate time series was observed at the beginning of the economic crisis. In this sense, the Greek case is likely the most alarming in Europe; as a matter of fact, Greece experienced a recent increase of violent deaths (Triantafyllou and Angeletopoulou 2011). Moreover, health implications of the economic crisis in Greece have concerned a growing interest (Kentikelenis et al., 2011; Economou et al., 2012). Such results assumed a pivotal importance in demographic studies as Greece had shown the lowest suicide rates up to the 1990s. However, the existing literature has focused on the relationship between people's health and the economic crisis, without assessing differential spatial patterns in mortality rate. High (and increasing) mortality rates

were recorded in recent times in compact urban areas concentrating economically-weak social classes vulnerable to recessionary shocks.

Comparison of demographic trends between Attica and the whole of Greece evidenced a variety of responses to economic crisis, expressing how crisis' impacts have been spatially distributed along urban-rural gradients (Maloutas, 2007). In this sense, changes in basic demographic indicators along the urban-rural gradient reflect the early influence of suburbanization in the 1980s and the increasing impact of the 2007 recession. At the same time, demographic polarizations in urban and rural areas have produced an increased divide between wealthier and disadvantaged socioeconomic contexts characterizing both high-density and low-density districts (Salvati et al., 2015a).

Taken together, results of this study suggest that population dynamics in Greece have been influenced by a combination of factors that include (i) a short-term impact of the economic cycle, (ii) a medium-term impact of suburbanization and (iii) a long-term impact of multiple social forces. Demographic dynamics along urban-rural gradients were progressively decoupled from population structure and socio-spatial characteristics and were more dependent on growth in personal income, spatial concentration of economic activities, rural development and accessibility (Kabisch and Haase 2011). Economically-marginal, rural areas were characterized by a progressive increase in mortality rates and low fertility rates (Gavalas et al., 2014).

Based on an informed empirical background from this study and earlier investigations, research is increasingly required to consider the impact of economic restrictions imposed by central authorities and cuts in public spending on population dynamics and socio-spatial configuration of urban and rural areas. Hypothesizing that demographic responses to recession depend on institutional decisions, such as the existence of specific policies to support families and the employment status (Goldstein et al., 2009, 2013; Livi Bacci 2013). the 2007 recession in Greece, and more generally in southern Europe, has altered the ability to social recovery after crisis, because of public spending cuts aimed at decreasing economic deficits (Bongaarts and Sobotka 2012). If current fertility oscillations are related to socioeconomic conditions (Martín-García 2013), design of effective social policies requires a comparative analysis of regional contexts since measures supporting family formation and childbearing may influence the actual situation of (future) parents in a different way among countries and among regions within the same country (McDonald 2006; Gauthier 2007; Van Nimwegen 2013).

3.11. Urban growth, spatial planning and the socioeconomic local context in Catalonia

Contemporary cities worldwide have progressively expanded in a scattered manner, giving rise to major changes in the use of peri-urban land, the increase of delocalized industrial activities and advanced services, and the consolidation of polycentric or scattered metropolitan structures (European Environment Agency, 2006). Urban growth is one of the most powerful drivers of change in land-use (Colantoni et al., 2015; Ferrara et al., 2015; Abrantes et al., 2016) and, in recent decades, its most remarkable spatial characteristics have coincided with sprawl (Antrop, 2000; Galster et al., 2001; Song and Knaap, 2004; Kasanko et al., 2006). Dispersed urbanization has shaped spatially-complex relationships between rural and peri-urban spaces (Schneider and Woodcock, 2008; Serra et al., 2013; Abrantes et al., 2016).

Urban expansion has inevitably transformed urban and rural landscapes, altering the spatial configuration of cities and regions, with negative environmental and socioeconomic consequences (Camagni et al., 2002; Petrov et al., 2009; Abelairas-Etxebarria and Astorkiza, 2012; Almeida et al., 2013). Every year, urbanization consumes thousands of hectares of cropland in Europe (European Environment Agency, 2006). The abandonment of marginal land has advanced, particularly in the Mediterranean basin (Serra et al., 2014; Vaz et al., 2015). In this context, regional planning is increasingly required to regulate urban expansion with the implementation of integrated and flexible approaches (Ratcliffe and Krawczyk, 2011).

Cited article

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In developed countries, the demand for land, land-use patterns, and their change over time are influenced by specific socioeconomic drivers (Maiello et al., 2011; Marraccini et al., 2015). Urban growth is fueled by increasing demand for housing, which influences economic and political determinants during decision-making processes about how much new land can be developed (Turok and Mychnenko, 2007). In this sense, a significant relationship between percentage of buildable land and per-capita disposable income has been repeatedly observed.

Planning rules hardly control the major transitions observed in contemporary cities (Brade et al., 2009; Abrantes et al., 2016; Lauf et al., 2016). According to Hall (1997), classical urban theories provide a partial interpretation of recent metropolitan dynamics. While mono-centric and compact spatial structures still represent the predominant urban form in Europe, processes of economic decentralization and population de-concentration have been advanced rapidly at least since the 1980s, shaping mixed and fragmented peri-urban landscapes (Kasanko et al., 2006). As one of the major challenges for regional planning, peri-urban contexts have been progressively characterized by mixed and fragmented development, with a rapidly changing socioeconomic base forming urban continuums (Nilsson et al., 2013). These include different dimensions of urbanization, which can result in local conflicts between competitive uses of land and complex location patterns of population, economic activities, and natural amenities.

New approaches to regional planning (Herold et al., 2005) and intense urban growth (Wey and Hsu, 2014) are devoted to understanding causes and consequences of discontinuous urbanization (Sakieh et al., 2015). Building scenarios and models evaluating spatial direction and intensity of

urban expansion, especially discontinuous urbanization, is increasingly required even if prediction accuracy may be limited in spatially-heterogeneous local contexts. Moreover, discontinuous urbanization consolidating scattered or polycentric metropolitan regions is demonstrated to be more sensitive to interactions with environmental, social, economic, and political factors than compact and mono-centric urban growth (Palang and Peil, 2010). Thus, urban governance increasingly requires a trans-disciplinary approach based on the development of scenarios' analysis and models of metropolitan expansion (Maiello et al., 2011).

Trend Impact Analysis (TIA) and Cross-Impact Analysis (CIA) are well-known and largely used scenario planning methodologies (Bradfield et al., 2005). These methodologies evolved out of the fact that traditional forecasting methods relied on the extrapolation of historic data without considering the effects of unprecedented future events. The concept of TIA and CIA involves four steps: (i) historical urban data are collected; (ii) an algorithm is used to select specific curve-fitting historical data and extrapolate this to generate 'surprise-free' future trends; (iii) a list of unprecedented future events which could cause deviations from the extrapolated trend is developed; and (iv) expert judgments are then used to identify the probability of occurrence of these unprecedented events as a function of time and their expected impact, to produce adjusted extrapolations.

Specific land-use approaches based on scenario-building have been developed in recent decades (Stewart, 2008; Dammers, 2010; Gantar and Golobic, 2015). Their application covers issues such as land-use planning, science and technology policy, organizational future-orientation, and societal challenges (Xiang and Clarke, 2003; Shearer, 2005; Dufva et al., 2015). They have several purposes: (i) to enrich the political debate, highlighting future territorial challenges; (ii) to engage with policy makers in the identification of major priorities, providing integrated decision support frameworks; (iii) to anticipate patterns and processes of change; and (iv) to foresee appropriate decisions, actions, and policies (Silva and Clarke, 2002; Uotila et al., 2005; Wiek et al., 2006). Moreover, these approaches assess the interaction between human and natural environments with the objective of identifying causes, mechanisms, and consequences of land-use dynamics, such as urbanization (Chaudhuri and Clarke, 2014).

Thanks to the increased availability of high-resolution geo-referenced information and accurate computer simulations (Veldkamp and Verburg, 2004), the integration between satellite imagery and Geographic Information Systems offers cost-effective and reliable information about patterns and processes of land-use (Serra et al., 2008; Haslauer et al., 2012; Liu et al., 2016). Quantitative models (based on deterministic or stochastic logic) and detailed spatial information contribute to scenario's analysis, informed planning decisions and assessment of how land management policies influence urban expansion (Silva, 2004).

As a result of a huge development of land-use change techniques, various models have been proposed to predict urban growth (Chaudhuri and Clarke, 2014), with a prominent role for approaches based on non-parametric methodologies, complex adaptive systems, fuzzy logic and automated machine learning. The SLEUTH model is a representative example predicting urban growth based on integrated information on Slope, Land-use, Exclusion, Urban extent, Transportation and Hillshade. The SLEUTH approach was extensively used to simulate growth of North American cities and European metropolitan areas (e.g. Silva and Clarke, 2002). Models are

usually evaluated depending on their predictive power (Li and Yeh, 2000; Kocabas and Dragicevic, 2006; van Vliet et al., 2013).

The elaboration of appropriate models of land-use change is contested for urban systems, whose complexity is shaped by self-organization processes (Wiek et al., 2006), non-linear interactions (Salvati and Serra, 2016), and emergent properties (Samet, 2013). Predicting future land-use change was demonstrated to be highly dependent on the selected growth-inducing factors; forecast estimates increase when deriving factors from an extensive analysis of past urbanization patterns (Kazemzadeh-Zow et al., 2017). The contribution of quantitative models to evaluation of short-term and long-term policy impacts on land-use transformations is also highly variable and was considered adequate only in some cases (Solecki and Oliveri, 2004).

Although simulations contribute to understanding how different land-use policies may influence future metropolitan landscapes (Dorning et al., 2015), urban growth models have additional limitations (Sharma et al., 2006). First, they provide only partial indicators to assess the impact of different urbanization patterns on urban sustainability. Second, the dissemination of a model's outcome is generally restricted to a small circle of experts. According to Rijkens-Klomp and Van der Duin (2014), scenario-based models are interpreted differently by national and local-level stakeholders due to lack of expertise when interpreting results of predictive methods. Third, models based on strict assumptions encounter difficulties when human decision-making and connections with other political processes are considered together (Dufva et al., 2015). Multiple urban forms and regional spatial structures, reflected in heterogeneous socioeconomic contexts at local scale, reduce the precision of models forecasting future patterns and processes of urban growth. In this sense, an empirical analysis of present and planned urban expansion in vastly different socioeconomic contexts may provide a more complete knowledge of urban growth factors considering spatial heterogeneity in planning practices, low predictability of economic agents' behaviour, and bio-physical territorial complexity (Abrantes et al., 2016).

Based on these premises, the impact of town master plans on future regional development was evaluated, with a statistical analysis of a database of land zoning indicators and background socioeconomic variables enriched with a bibliographic analysis of long-term urban expansion in Catalonia, Spain. Catalonia is a representative European region with a long planning tradition and a diversified economic structure based on small, mostly family-owned, firms and large multinationals (Serra et al., 2013). In the aftermath of World War II, different settlement models have been consolidated in Catalonia, including mono-centric and compact cities (Barcelona and, at a less pace, the three provincial capitals, Girona, Lleida and Tarragona), polycentric expansion around central cities (especially in the Barcelona metropolitan region), medium-density, discontinuous settlements along the sea coast and low-density, dispersed expansion in upland and mountain districts with natural amenities. The presence of multiple urban forms coexisting in the same region claims for an improved knowledge of socioeconomic mechanisms at the base of recent urban growth and how they can influence short-term future expansion of residential settlements.

Under the hypothesis that an exploratory analysis of a large set of contextual variables may provide the necessary basis for realistic predictions of future urban growth in spatially-heterogeneous regions (Salvati and Carlucci, 2014), indicators of land zoning derived from Municipal Master Plans were used to analyze recent urbanization patterns and processes and to

formulate local-scale scenarios of urban growth, taking into account differentiated socioeconomic contexts underlying planning decisions. By assessing the relevance of physical, environmental, and socioeconomic constraints to urban expansion, the work done contributes to design of urban growth models that incorporate the effect of planning decisions and place-specific land management policies that will contain urban expansion and promote a spatially balanced development.

3.11.1. A bibliographic analysis of spatial trends in urban growth

The Autonomous Community of Catalonia in northeast Spain, a developed region extending nearly 32,000 km^2 along the elevation gradient from the Mediterranean Sea to the Pyrenees mountains, consists of 4 provinces (Barcelona, Girona, Lleida, Tarragona) and a total of 946 municipalities. Municipalities were considered the basic unit of analysis, given the relative ease of detecting changes in land-use in this spatial domain. Empirical results related to these local administrative units can be readily used by policy-makers, planners, and non-technical users in decisions regarding land-use (Chorianopoulos et al., 2010). Using municipalities as the unit of analysis allowed reliable comparisons with external data sources, such as official economic and socio-demographic surveys (Salvati et al., 2017).

Data analysis was articulated across various descriptive and multivariate statistical processes. The share of buildable land in a total municipal area was assumed as the most relevant variable for estimating future urban growth in Catalonia. Three additional variables were calculated: percent buildable land for residences or services in total buildable land and the ratio of buildable land to non-buildable land at the spatial scale of local municipalities. A total of 80 indicators were considered (grouped as relating to demography, economy, society, environment, and topography) to assess the socioeconomic context underlying planning decisions in each studied municipality. Linear distances were calculated from each municipality to the 4 provincial capital cities and 9 sub-centers (Granollers, Sabadell, Terrassa, Vilafranca del Penedès, Vilanova i la Geltrú, Manresa, Vic, Berga, Mataró) (Figure 3.45). According to Muñiz and Garcia Lopez (2010), specialized jobs in finance, insurance, real estate, research, and development sectors are concentrated in Barcelona's sub-centers. Soil sealing, considered a proxy of urban concentration in Catalonia, was assessed using a raster map of built-up and non-built-up areas produced by the European Environment Agency (2011) and including continuous degree of soil sealing, ranging from 0% to 100% in a 100 m grid. Sealed surfaces include paved structures (roads, sidewalks, driveways, and parking lots) covered by asphalt, concrete, brick, stone, and rooftops (European Environment Agency, 2006). Soil sealing indicators were calculated as the percent area of 10 classes (1% to 10%, ..., 91% to 100% impervious land) in total municipal area, reflecting the overlap between the soil sealing raster map and the shapefile of municipal boundaries in Catalonia.

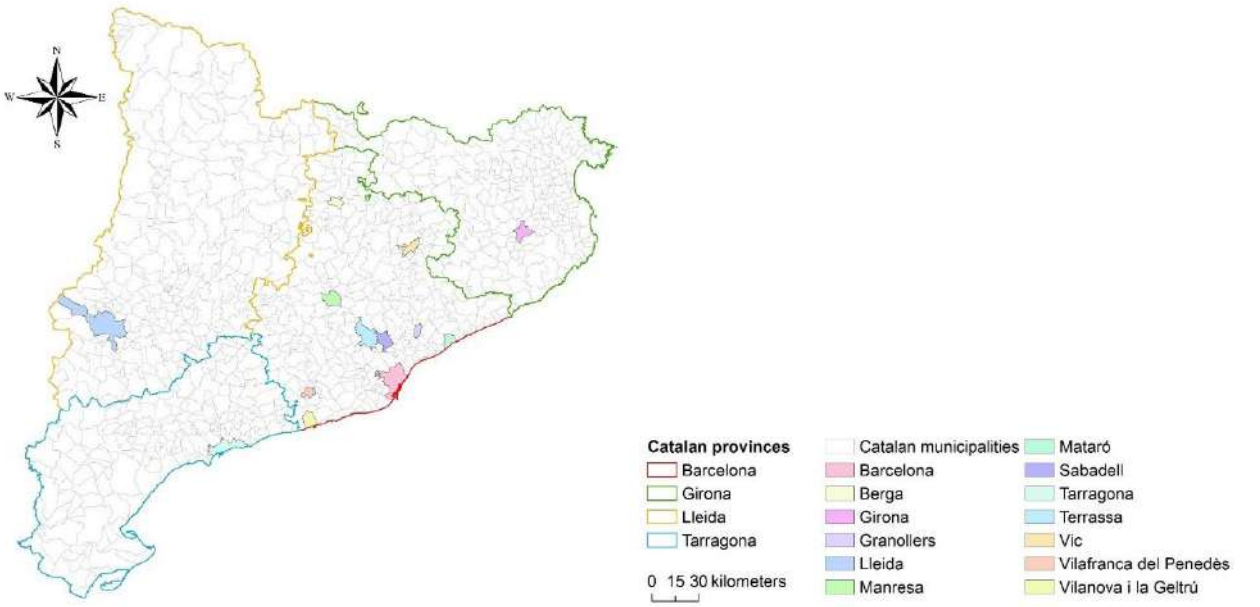


Figure 3.45. Catalan municipalities regrouped into the provinces of Barcelona, Girona, Lleida, Tarragona in the entire Autonomous Community of Catalonia.

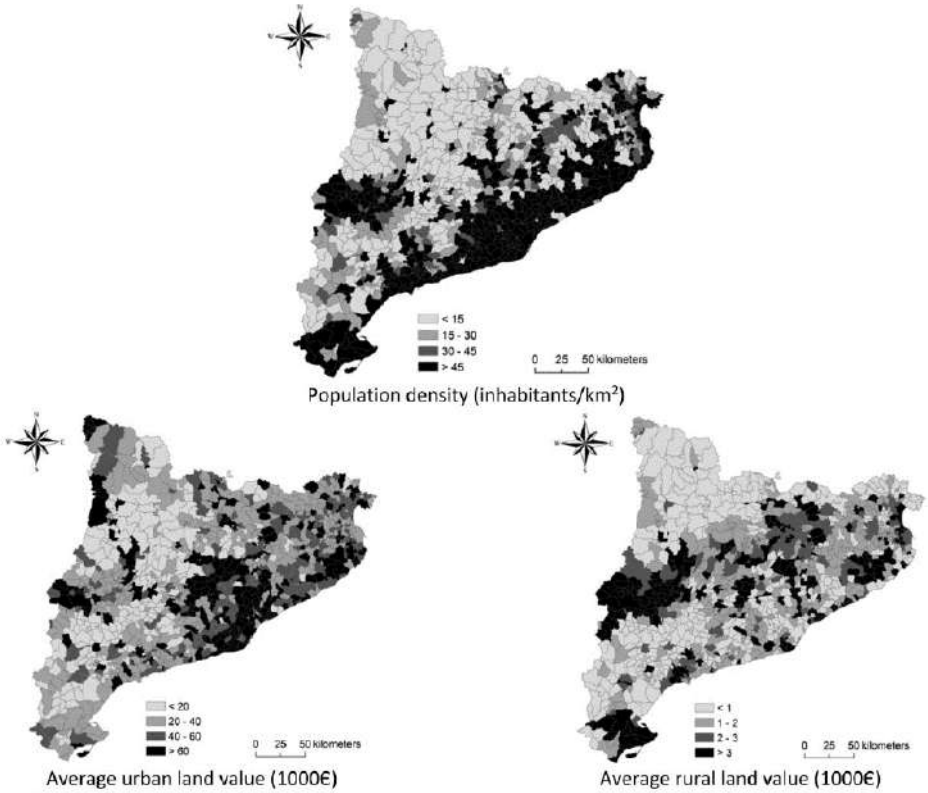
Pair-wise correlations between the 4 variables prefiguring future urban growth (share of buildable land in total municipal area, percent buildable land for residences or services in total buildable land, and ratio of buildable land to non-buildable land) and the 80 indicators illustrating socioeconomic conditions in each municipality were assessed using a non-parametric statistical analysis based on Spearman rank coefficients. Spearman correlation analysis was run pair-wise between contextual indicators and variables derived from land zoning and allowed the identification of candidate drivers of urban change (Salvati and Carlucci, 2014). Significance was tested at $p < 0.05$ after Bonferroni correction for multiple comparisons under the null hypothesis of non-significant relationship between a given variables' pair. Instead of performing more common linear correlations based on Pearson product-moment coefficients, non-parametric correlations were selected due to less stringent distributional assumptions (i.e. allowing the analysis of data with marked deviation from normality) and the ability to identify both linear and non-linear pair-wise relationships.

A multivariate statistical analysis, the so-called Principal Component Analysis (PCA), was used to identify municipalities with homogeneous socioeconomic profiles, removing redundancy and highlighting multiple relationships among socioeconomic variables (Salvati et al., 2017). The PCA is a common multidimensional technique aimed at exploring many variables by selecting a reduced number of relevant unobservable (latent) components. These components were derived as a linear combination of the measured variables and explain a large proportion of the total variance reflected in the eigenvalue relative to each component. Principal Component Analysis is an adequate tool to uncover major data structures and patterns, investigating multiple correlations among variables and reducing redundancy in the input data matrix. The analysis was run on a data matrix of 84 variables (4 derived from land zoning and 80 contextual indicators) observed for each studied municipality, with no missing data. Variable loadings on components with eigenvalue > 1 were considered in the analysis.

3.11.2. Assessing socioeconomic contexts

The spatial distribution of selected social, demographic, economic, and cultural variables (Figure 3.46) provides a preliminary assessment of the different local contexts characterizing Catalan municipalities and provinces. Population density showed medium-high values along the Mediterranean Sea coast and near the largest cities, especially Barcelona. The highest values of urban land rent were observed in the municipalities surrounding Barcelona and in the neighbouring Vallès districts, where many sub-centers and medium-size towns are located (Terrassa, Sabadell, Granollers, Sant Cugat del Vallès). In contrast, the highest rural land rental values were observed in internal lowland districts specializing in irrigated farming around the city of Lleida, in coastal districts of Tarragona province bordering the Ebro river, and in sparse rural areas of Girona province. Based on the spatial distribution of workers in the secondary sector, industrial activities were found concentrated around Barcelona and in internal districts of Girona province.

Most of the resident population that reported writing in Catalan, taken as an indicator of autochthonous population, was concentrated in internal and mountainous areas of the Pyrenees district and the provinces of Barcelona and Girona, with percentages decreasing in coastal and urban areas experiencing migration from abroad and from various regions of Spain. Agricultural utilized area was concentrated in north-western municipalities of Lleida provinces; fragmentation of farmland (per-farm agricultural utilized area) was higher in the coastal belt of Barcelona and in Lleida and Tarragona provinces.



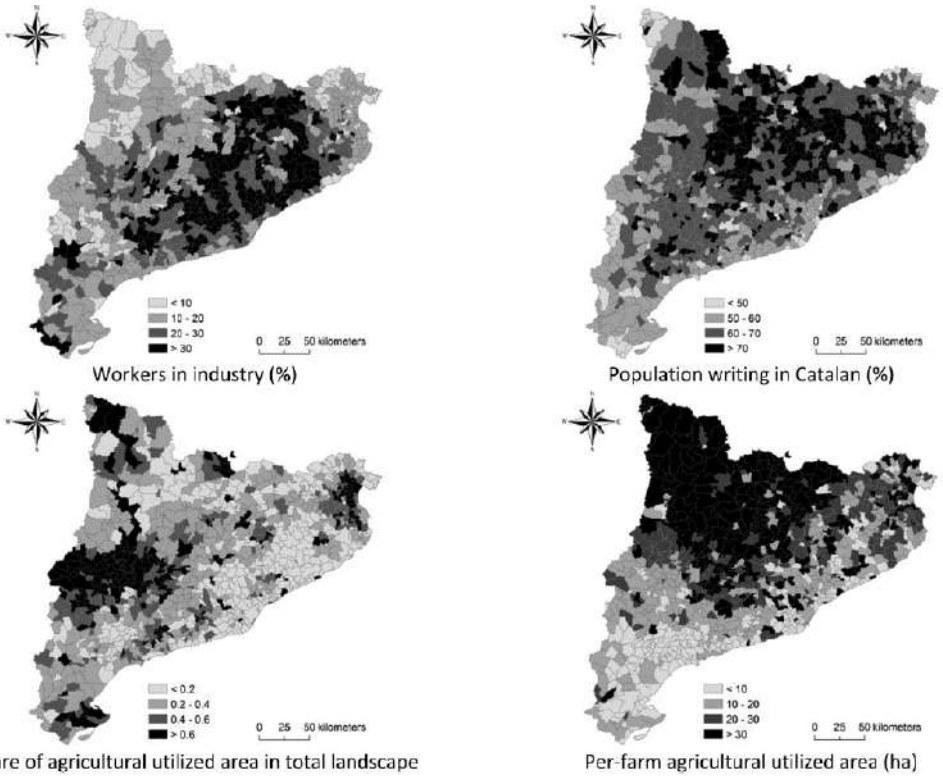


Figure 3.46. The spatial distribution of selected variables in the metropolitan region of Barcelona.

3.11.3. Profiling Catalan municipalities according to the amount of buildable land

The share of buildable land in total municipal area and the ratio of buildable to unbuildable land indicates a substantial fragmentation of rural spaces: the highest values were concenterd in suburban areas with intermediate and low density of built-up areas (Figure 3.47). Based on municipal town plans, only 5 municipalities (Puigdàlber, Premià de Dalt and Vallbona d´Anoi situated in Barcelona province, Vilamacolum, Girona province, and Puigpelat, Tarragona province) could see substantial growth (>50% of existing built-up area) in urban settlement (Figure 3.48). In most Catalan municipalities, master plans allowed for low or moderate expansion of urban settlements (<50% of existing built-up area). In lesser-populated towns, building expansion could double the current extension of urban settlements. The highest share of buildable land in total built-up area was observed in municipalities with <1000 resident inhabitants and located further away from Barcelona, decreasing linearly with population size. However, the highest ratio of buildable land to total municipal area was observed in medium-sized towns with population ranging from 10,000 to 50,000 and decreased linearly with the distance from Barcelona.

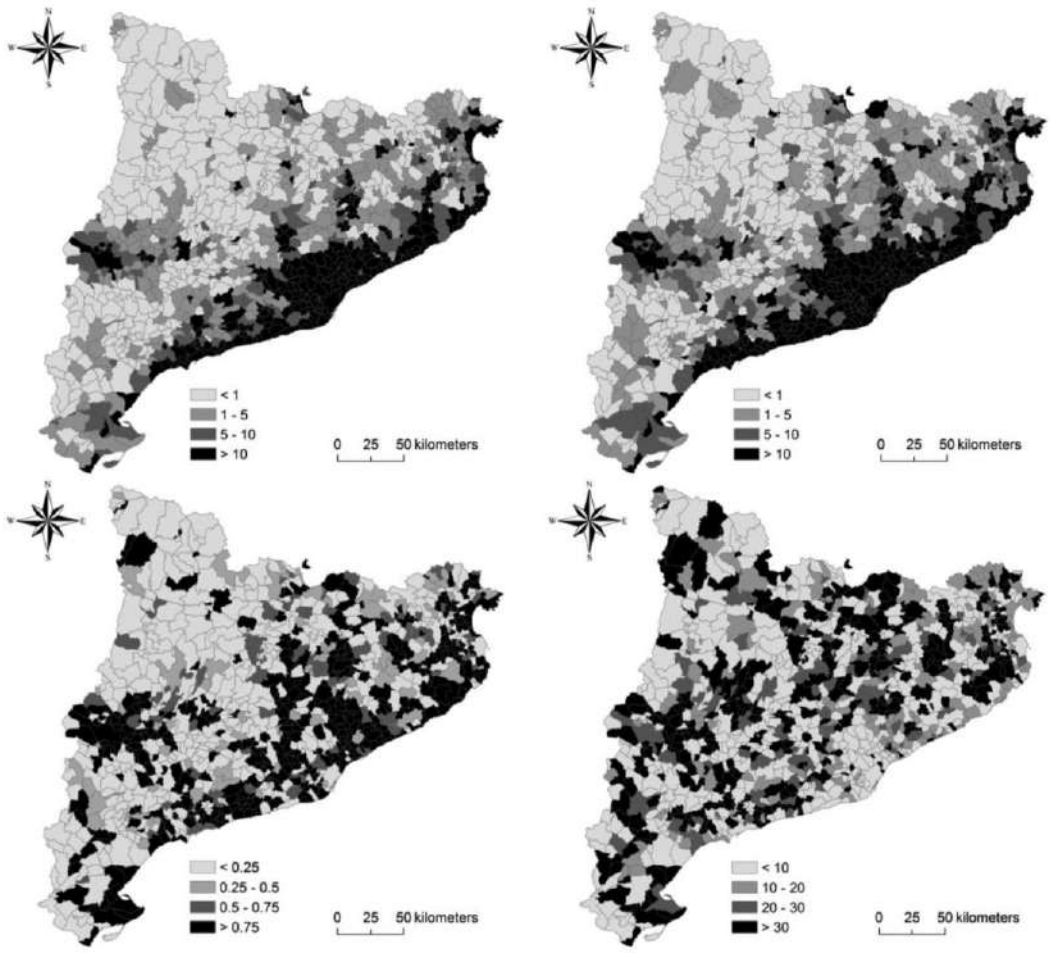


Figure 3.47. Profiles of built-up area of Catalonia in 2011.

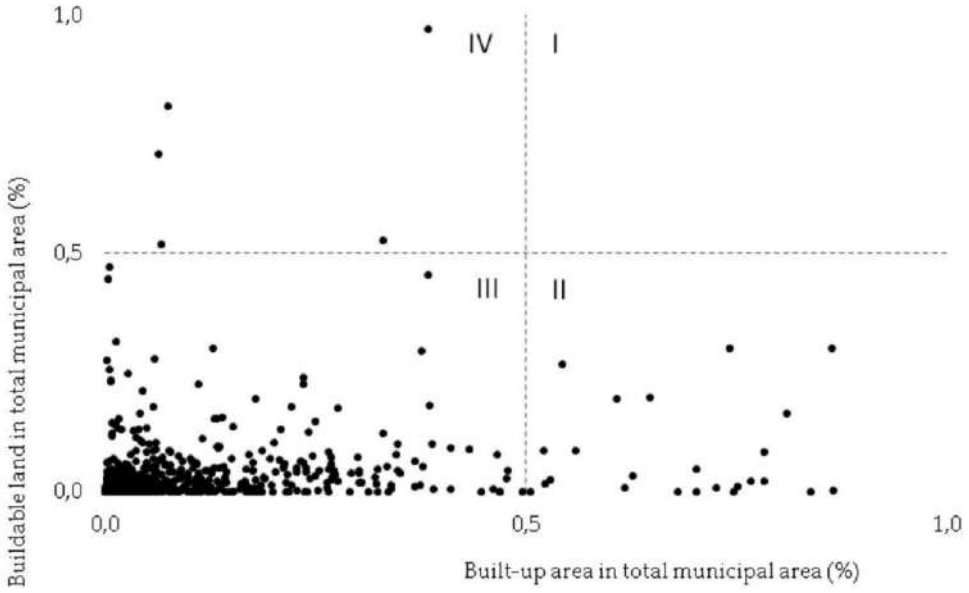


Figure 3.48. The relationship between the percentages of built-up area (2011) and buildable land in each municipality of Catalonia (quadrant I: compact urban municipalities under saturation; quadrant II: consolidated urban municipalities; quadrant III: rural municipalities with moderate-to-low supply of buildable land; quadrant IV: suburban municipalities with high availability of buildable land).

Local scenarios based on land zoning predicted a contained urban expansion for municipalities in Tarragona and Barcelona provinces, with a high amount of buildable land observed in Girona and Lleida provinces. Indicators of urban centrality calculated at the regional scale, especially decreasing measures of spatial variability and concentration of built-up area (skewness, and kurtosis), and increasing median-to-average ratio of built-up area, suggest that future urban spatial structure may consolidate polarizations in the most accessible coastal and flat districts and the less accessible, inland rural areas. Denser frequencies of municipalities with intermediate share of built-up area in total municipal area under town plans' urban scenarios observed from the 2011 data corroborate this hypothesis (Figure 3.49).

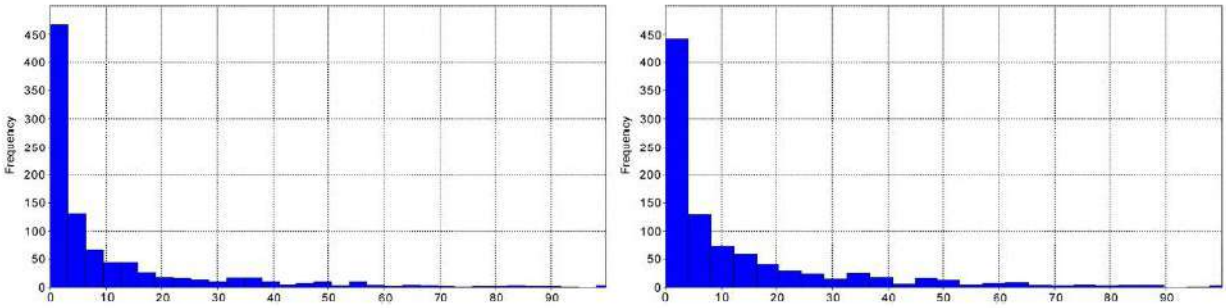


Figure 3.49. Statistical distribution of Catalan municipalities by built-up area in total municipal area (left: urban fabric 2011; right: urban scenario based on amount of buildable land prescribed by each municipal town plan).

Results of a non-parametric Spearman rank correlation analysis between selected variables derived from land zoning and context variables show the positive correlation between the share of buildable land in total municipal area and population density, population growth (2001-2011), density of one-member households, and medium-to-low levels of soil sealing. The proportion of buildable land at the municipal scale decreased significantly with municipal size and density of trucks. Taken together, this correlation profile is analogous to what was observed for the share of residential and service areas in total municipal area and for the ratio of buildable land to unbuildable land. These results pointed out that different types of planned urban expansion occurred coherently in similar socioeconomic contexts. The PCA results identified latent variables characterizing urban expansion in Catalan municipalities. Component 1 (19% of total variance) identified the urban-rural gradient in Catalonia as being associated to specific morphological and functional variables (soil sealing, vertical profile of buildings, unemployment rate, one-member households, housing regime, distance from inner cities). Component 2 (8.9% of total variance) identified a land-use gradient distinguishing flat and accessible areas specialized in agriculture from forested land in mountainous districts further away from the main urban centers. Finally, component 3 (7.3%) discriminated rural areas with an economic base dominated by industry from districts specialized in service activities at relevant distances from Lleida, Tarragona, and other sub-centers west of Barcelona. The highest amount of buildable land in total area was observed in rural and suburban municipalities displaying a service-specialized economic structure.

3.11.4. Prefiguring a Future City in Catalonia

Catalonia is a European region that has been subject to evident spatial changes in recent decades (Catalàn et al., 2008; Nel-lo, 2011; Serra et al., 2013). With urbanization being a major driver of land-

use change in Europe, transformations of peri-urban areas following suburbanization have specific impacts on economic activities, people's lifestyle and urban morphology (Aguilar, 2008). In fact, territorial transformations in Catalonia have particularly affected the peri-urban contexts, influenced by place-specific drivers as cultural, social and economic factors (Salvati and De Rosa, 2014). Landscape transformations, observable in several metropolitan regions in Europe, have been increasingly influenced by latent social, political, and economic factors consistently observed in both urban and rural areas (Antrop, 2000), claiming for a truly integrated (socioeconomic and environmental) planning approach to metropolitan sustainability. For this reason, it is essential today to prevent and manage complex contexts, such as metropolitan region, ensuring sustainable and appropriate development and considering that local contexts might be influenced by planning choices toward explicit land use rules (Abrantes et al., 2016).

Research seeking new, and better-performing models of land-use change offers a guide to understanding land-change dynamics and can help policy-makers to make decisions supporting urban sustainability. However, modellers usually entrust themselves to physical changes in land-use assessed through the detection of land-use change, reducing the role of regional planning (Briassoulis, 2000). Although planning is a key element of landscape transformation, land zoning has been infrequently considered in urban growth models. Tools integrating spatial data derived from town master plans with information derived from models forecasting urban expansion are especially needed to shed light on the recent evolution of metropolitan regions in Europe.

In this line of thinking, a series of adjustments in the strategic background of sub-national governance have stimulated scenarios-based models supporting new forms of urban and regional governance (Puglisi and Marvin, 2002). The impact of local land-use regulations on urban development has been sometimes examined using predictors assessing morphological attributes and the local socioeconomic profile (Levine, 1999; Nilsson et al., 2013). However, since spatial heterogeneity has seldom been considered in land-use simulations based on multiple predictors, planners and policy makers still prefer to use single trend-based reference scenarios, being intended as easily interpretable and requiring few input data (Koomen et al., 2011).

The novel contribution of the work in this line of thinking was to assume town master plans as a realistic scenario of urban growth. Based on extensive analysis of the most recent master plans approved in (urban and rural) Catalonia's municipalities and a set of background socioeconomic indicators, current and future urban expansion was compared under the hypothesis that local contexts may influence planning decisions toward (more or less) stringent land use regulations (Abrantes et al., 2016).

In this way, the approach presented enriched with a bibliographic analysis of long-term urban expansion in the area, allows discriminating between local contexts based on their intrinsic bio-physical and environmental features (e.g. consolidated urban morphology, spatial distribution of sealed land, distance from central cities, elevation, natural amenities), economic variables (accessibility, production structure, job market performances) and socio-demographic attributes (population density, household structure, housing characteristics), outlining the multi-dimensional and place-specific relationships between urban planning, land-use change, and socioeconomic local contexts. Multivariate statistical techniques were used to assess the spatial association between land zoning and the underlying socioeconomic background, indirectly evaluating the effectiveness of

planning codes that limit metropolitan expansion and promote urban containment (e.g. improving regulation compliance and increasing regulation stringency on both greenfield's and browfield's development) or, at least, a polycentric and spatially-balanced development with moderate urban expansion (e.g. increasing regulation stringency on greenfield's development). In this way, this study aimed to understand whether urban growth - especially in the form of discontinuous settlements - can be more effectively contained by acting on a given set of socioeconomic factors at local and, possibly, regional scale (Munafò et al., 2010).

Since the 1980s, the predominant urban spatial structure in Catalonia has been associated with a mono-centric model influencing settlement expansion in coastal municipalities with rapid tourism development (Cuadrado-Ciuraneta et al., 2017). More recently, Catalonia's spatial structure has been defined as mixed scattered (Muñiz et al., 2010) and polycentric (Catalàn et al., 2008). However, contrary to what was hypothesized (and partly observed) in the early 2000s (Muñiz et al., 2003), the future expansion of planned settlements in Catalonia will contribute moderately to rebalance cities' hierarchy, consolidating resident settlements in the outer belt of Barcelona and around the three provincial capital cities (Girona, Lleida, Tarragona).

Socioeconomic transformations have stimulated settlement dispersion around the major Catalan sub-centers, causing extensive land consumption (European Environment Agency, 2006). Infrastructure-driven pressure and a generalized increase in the price of fringe land have been considered additional drivers of change (Serra et al., 2013). At the same time, depopulation and land abandonment have been extensively observed in the Catalan Pyrenees and in some inland municipalities specialized in dry farming and traditional crops. Population concentration in major towns has contributed to the depopulation of municipalities with limited communication networks (Serra et al., 2014). Finally, a progressive forestation of abandoned land can be observed in the Pyrenees district as a result of depopulation and loss of traditional agricultural activities.

Results obtained indicate that future urbanization in Catalonia will increasingly involve rural, medium-density areas, prefiguring urban expansion because of population growth, mixed densification/deconcentration of economic activities, and specific social profiles. As suggested by Nel-lo (2011), population de-concentration has produced (and will produce soon: Cuadrado Ciuraneta et al., 2017) suburban spaces with moderately dispersed forms and mixed economic functions, as already observed in other Mediterranean cities, such as Naples (De Rosa and Salvati, 2016), Rome (Di Feliciantonio and Salvati, 2015) and Athens (Salvati and Serra, 2016). Although the highest percentages of buildable land were found in peri-urban municipalities, the most accessible rural areas, especially flat districts along the Mediterranean Sea coast, will experience extensive urbanization (Smith, 2005). While high percentages of buildable land were generally observed in municipalities with a demographic structure dominated by one-member households, the spatial distribution of buildable land in Catalonia's municipalities was associated neither with land rent nor with distance from the main urban centers. These evidences suggest how future urbanization processes will be partially decoupled from Catalonia's urban hierarchy, involving accessible rural areas progressively further away from central cities (Salvati and Carlucci, 2014).

Concerning peripheral rural areas, although local development related to protected areas and eco-tourism was promoted in the Pyrenees district and is associated with sparse urbanization, second-home expansion and eco-tourism development (Barbati et al., 2013; Ferrara et al., 2014;

Colantoni et al., 2015), depopulation and land abandonment reflect a persistent lack of infrastructure and jobs in marginal, mountainous districts. In these areas, other than promoting light urbanization and infrastructure development, municipal town plans seem to consolidate economic marginalization and population decline.

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4. Evolving threats to the agricultural sector and the peri-urban landscape

4.1. Land abandonment in the Mediterranean basin

Worldwide land-use changes have relevant environmental implications including polluting soil and water and releasing carbon dioxide and other greenhouse gases (Collins et al., 2000; Zipperer et al., 2000; Bruegmann, 2005). Landscape fragmentation and habitat destruction exert strong pressures on biodiversity. Decisions about land-use involve trade-offs between diverse sectoral interests, including industry, transport, mining, agriculture and forestry (Zhang et al., 2004; Jomaa et al., 2008; Shrestha et al., 2012; Salvati et al., 2013). Managing these trade-offs in a way that maximizes society's wellbeing - both today and in the years ahead - requires an integrated policy approach incorporating environmental considerations (Barbati et al., 2013). Designing and implementing an integrated policy approach is impossible without accurate geo-spatial information, including accessible data on land cover and analysis of land-use changes (Briassoulis, 2001).

Demand for land is particularly high in Europe (Antrop, 2004). Food and biomass production, housing, infrastructure and recreation all compete for space, with impacts on climate, biodiversity and ecosystem services (Pauleit and Duhme, 2000). In a recent assessment, the European Environment Agency (EEA) analyses pan-European land-use changes, concluding that an integrated policy approach based on reliable data to balance sectoral demands and manage land sustainably is increasingly required (Munafò et al., 2013). This assessment program covering 36 European countries and a total area of 5.42 million km^2, shows that the spread of urban areas and transport infrastructure has been accelerating in Europe; artificial land cover increased by 3.4% over 2000-2006, by far the largest proportional increase in all land-use classes. Conversely, farmland is decreasing in terms of area but is often managed more intensively, partly due to growing demand for bio-energy crops. Wetlands and biodiversity-rich natural and semi-natural areas also continue to decline, although at a slower rate than observed in the time interval between 1990 and 2000 (European Environment Agency, 2010).

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As urban sprawl is strictly connected to the morphological, environmental, political, social, cultural and economic characteristics of the territory over which the phenomenon is acting, earlier contributions have defined sprawl as a typical United States phenomenon (Bruegmann, 2005). From this point onwards, the importance of adopting an ad hoc analysis for studying patterns and processes of sprawl according to the investigated region has been stressed (Alphan, 2003; Cakir et al., 2008; Catalàn et al., 2008). Earlier studies have demonstrated how this urban phenomenon varies within the same continent and even the same geographical region (Salvati and Ferrara, 2013). A picture on the urban development trajectories of the European regions has been given with the use of defined urban trends (e.g. Sarvestani et al., 2011). Successively, through data provided by official statistics, dynamics and spatial effects of urban sprawl in Europe, and especially in the Mediterranean region, have been described and quantified extensively (Musterd, 2005; Maloutas, 2007; Arbaci and Malheiros, 2010; Ferrara et al., 2014), concluding that nature and spatial outcomes

of sprawl reflect geo-economic and socio-cultural characteristics of the territory and its settlements (e.g. Soliman, 2004; Serra et al., 2008; Kroll and Kabisch, 2012; Pili et al., 2017).

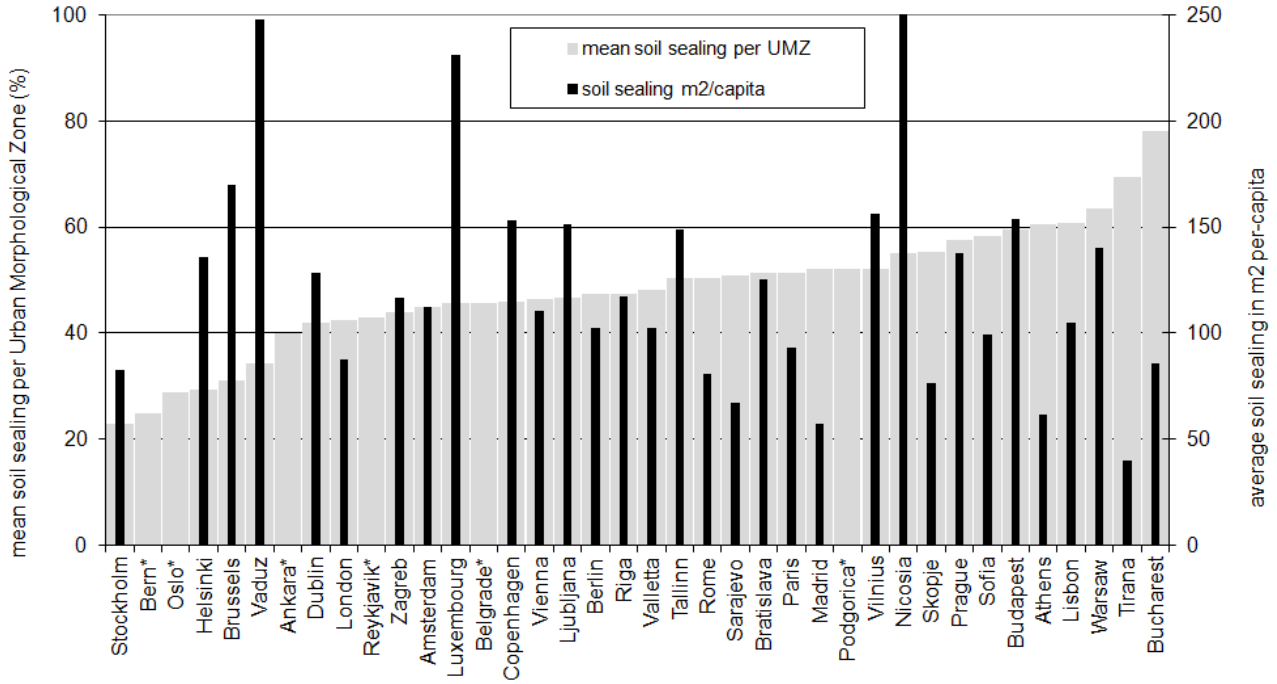


Figure 4.1. Descriptive statistics of urban growth and soil sealing rate for selected metropolitan regions in Europe.

Peri-urban areas, sea coasts and internal lowlands were the areas of higher population growth across the Mediterranean basin (Salvati and Ferrara, 2014). Consequently, in order to understand the true nature of urban sprawl in the Mediterranean basin, it is definitely important to provide an historical, geographical, economic, social and cultural description of the Mediterranean urban landscapes (Allen et al., 2004; Maloutas, 2004; Arbaci, 2008; Serra et al., 2014). This analysis should be also focused on the comprehension of the Mediterranean urban ideal and how the cities of the region are shaped by certain patterns and practices of the population (Kazepov, 2005). A thorough picture of present and future state of urbanization in the Mediterranean region should consider multiple issues including (i) present condition and scenarios of demographic growth and urban development (ii) spatial patterns and trajectories of urbanization, (iii) environmental impacts of coastalization processes and (iv) how socioeconomic vulnerability of Mediterranean cities is evolving with regards to urban expansion and future demographic scenarios (Zitti et al., 2015). Empirical results of these studies may support the adoption of more specific, scale-dependent policies aimed at containing urban-rural disparities (Carlucci et al., 2016). The present study proposes a specific analysis of urban expansion in a representative case study in southern Europe, the metropolitan region of Attica in Greece, exploring socioeconomic drivers of urban transformation and environmental implications of settlement sprawl, with special regard to the notion of land-use efficiency. The present work is intended to provide a specific contribution on dispersed urban expansion, shedding further light on latent transformations of Mediterranean cities, progressively abandoning a compact urbanization and moving toward discontinuous metropolitan spatial structures.

4.1.1. Representative Mediterranean compact region

The metropolitan region of Attica encompassing the greater Athens' area, extends nearly 3000 km^2 in Greece, being administered as a regional authority classified in the Nuts-2 level of the European Territorial statistical nomenclature defined by Eurostat. Being partitioned in four local prefectures (Figure 4.2), Attica's land consists of uplands and mountains (up to 1413 m at the sea level) bordering the urban area of Athens and three coastal plains (Messoghia, Marathona and Thriasio), together with some islands among which Salamina and Egina are the most populated (Rontos et al., 2016).

The assessment of dispersed urban expansion in Attica has performed with the use of multiple indicators (Nikolakopoulos et al., 2005; Weber et al., 2005; Christopoulou et al., 2007) based on mainstream literature (e.g. Marcucci, 2000; Cook, 2002; Verburg et al., 2004; DiBari, 2007; Weng, 2007; Detsis et al., 2010). Due to the nature of the adopted variables, these will evidence characteristics regarding the anatomy (physical features) and the essence (conceptual elements) of the phenomenon being investigated (Jaeger, 2000; Luck and Wu, 2002; Li and Wu, 2004; Kazemzadeh-Zow et al., 2016). All these analyses will bring to various hypothesis on the nature of the sprawl process in Attica. In this sense, an ad hoc analysis of this specific phenomenon for the Mediterranean region has revealed essential (Mavrakis et al., 2015). Various methodologies based on different morphological indicators (e.g. building activity, land-use, demography) and specific considerations on the history and culture of the investigated region were considered here with the aim to produce multifaceted results shedding light on the true nature of socioeconomic processes underlying sprawl in Attica.

4.1.2. Assessment of altering peri-urban landscapes

Evident transformations of the traditional compact poly-centric urban asset of Attica (mainly based on the Athens-Piraeus dipole) have been observed. The typical urban-rural polarization representative of many Mediterranean urban structures has been slowly replaced by extended urbanization over the majority of the available and "made" available land (through illegal occupation and construction activities over forest, semi-natural and agricultural areas) of the region (Moissidis and Duquenne, 1997). This process of transformation has been developing since the first years of the 20th century. However, since the 1980s, Mediterranean compact growth was being replaced with greater rapidity by sprawling patterns in a demographically stable context (Arapoglou and Sayas, 2009). As a matter of fact, since the end of the 1970s, building activity has mainly concentrated in the available spaces located in the land plains of the region and in greater Athens (Burgel, 2004). The development rates of new built-up areas have been the highest between 1971 and 1985 and have gradually decreased until the early 2000s (Figure 4.4). In the year 2009, the total population of Greece was estimated to 11,260,402. More than one third of the country's inhabitants concentrated in Attica, making it the most densely populated region of Greece (Table 4.1).

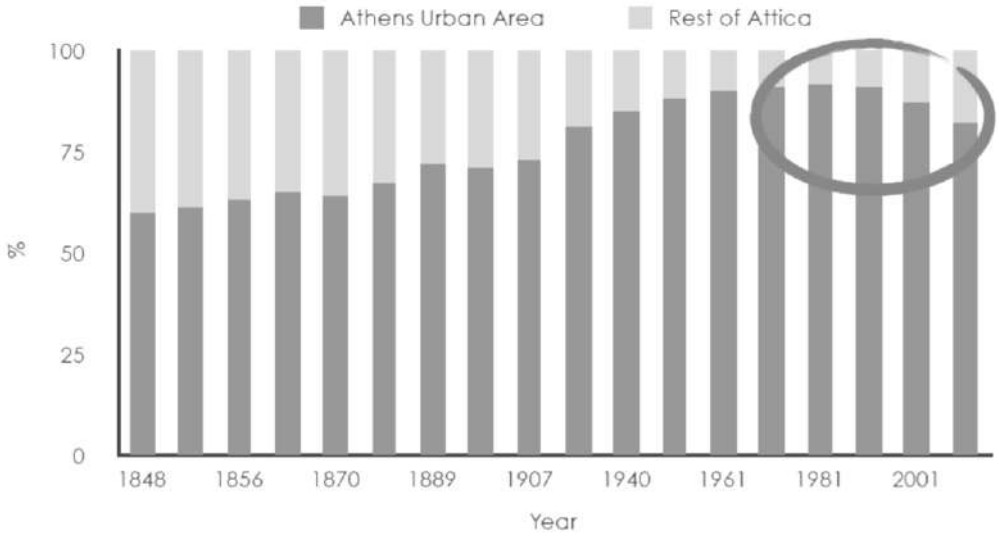


Figure 4.4. Population distribution (%) throughout Attica, 1848-2011.

Since the early 1960s, the expansion of the central city has occurred mainly at the expense of agricultural and forested land, according to statistical data provided by Hellenic Statistical Authority (ELSTAT). While in the 1960-2000 period urban areas have increased by nearly 20%, agriculture and forested areas have decreased respectively by 12% and 4% (Figure 4.5). Earlier analysis has evidenced a negative correlation between the (increasing) built-up areas and the (decreasing) agricultural lands at all investigated times and a weaker one between (increasing) urban areas and (decreasing) pasture and forested land (Ferrara et al., 2015). This means that urbanization is playing a crucial role in transforming Attica landscape especially with regards to cultivated and agricultural areas.

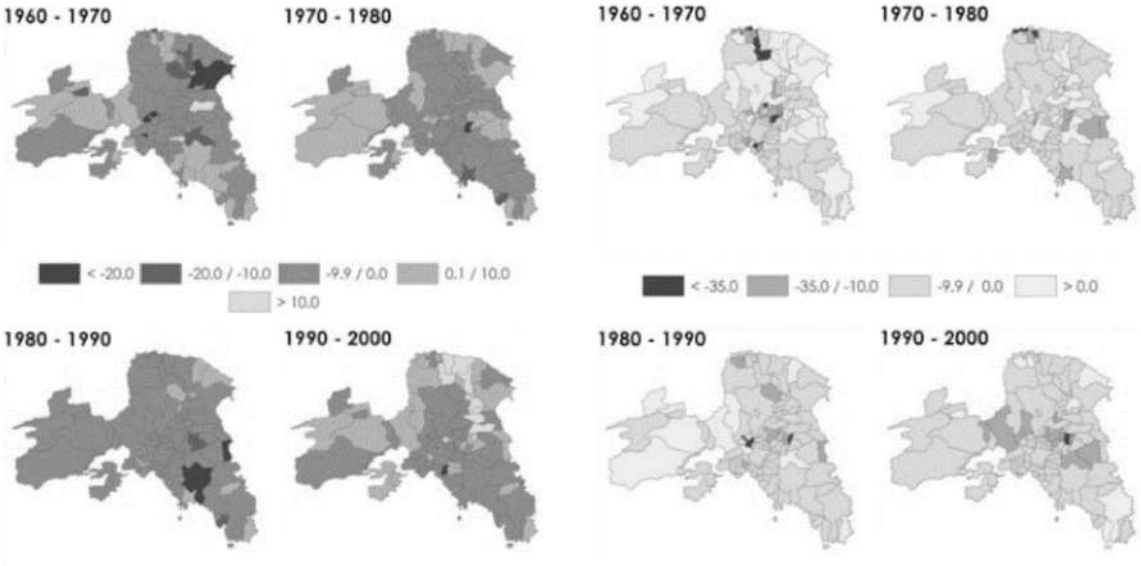


Figure 4.5. Selected land-use patterns of change (% in total land surface) in the study area, 1960-2000 (left: agricultural areas; right: pastures).

Detailed information on landscape transformations were obtained by analyzing statistical data on the surface of cultivated land in Attica by type of cultivation. Between 1963 and 2006 the total cultivated land of Attica has significantly decreased, with a total loss by nearly 343.9 km^2 (Table 4.2). More specifically, by looking at the land surface of the various types of cultivations, the greatest

percent decrease (calculated from the initial value in 1963) has occurred for crops and arable land (-74.8%), followed by vines (-58.0%) and vegetables (-21.9%). The only exception to this negative trend is represented by areas destined to trees in compact plantations, that have increased their surface by 90.5 km^2.

Table 4.2. Surface of cultivated land by type of cultivation in Attica, 1963-2000.

Year	Cultivated land in Attica by type of cultivation (km^2)				
	Total cultivated land	Crops on arable land	Vegetables	Vines (grapes and raisins)	Trees in compact plantations
1963	855.0	420.6	82.4	175.5	176.5
1971	586.2	180.0	55.6	176.2	174.3
1981	700.4	190.7	53.9	164.4	291.5
1993	646.1	159.4	55.9	139.1	291.7
2000	630.5	133.6	58.5	113.3	325.1
2006	511.1	106.0	64.4	73.7	267.0

Land abandonment is outlined by the increase of fallow land between 1971 and 2000 (Figure 4.6). This variable can be interpreted as a proxy of the quantity of land "waiting for urbanization". The above analysis on land cover variation yields to the conclusion that the conversion of semi-natural lands to urban areas in Attica involved primarily agriculture zones over the investigated temporal period and, at a smaller pace, forests and pastures. Land consumption in the first-time period (1960-1970) was mainly concentrated at the urban-rural interface involving land devoted to agriculture and, in the following time period (1970-1980), the surrounding forest land. The last period investigated (1990-2000) was characterized by a progressive abandonment of cultivated fields and the subsequent conversion of woodlands to pastures due to recurrent wildfires.

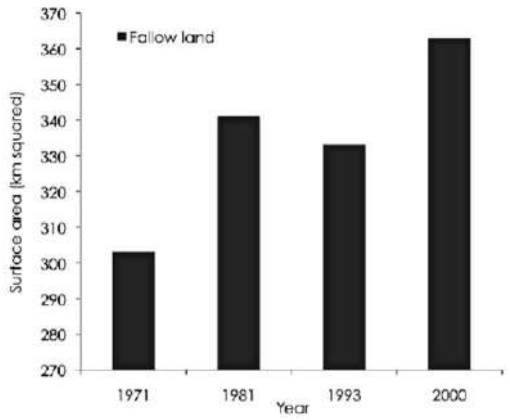


Figure 4.6. Total surface of fallow land in Attica by year of investigation.

Generally, areas characterized by a predominance of low height buildings are likely to be localities targeted by sprawl process. On the contrary, areas characterized by high buildings are typical of compact cities. Intermediate residential density areas, represented by the distribution of buildings with maximum one-two floor(s), are mostly located around the first peripheral ring of greater Athens, in the Messoghia and Thriasio plains and along the Western and Eastern sea coasts of the region. Figure 4.7 shows how the building activity of the region grew until the end of the 1970s when reaching its maximum levels (158,623 new constructions in the time period 1971-1980), and later started to rapidly decline. Since 1945, buildings were mostly constructed with no floors (besides

the ground level), giving up terrain to buildings of 2 and 3 floors above all. In fact, in the following years buildings of high vertical profile (3 to 6 or more floors) increased (while all the other classes either declined or remained stable). With some approximation, this result evidences the period of compact growth of the central urban area of Attica. Since the end of the 1990s, the development of built-up areas has undergone substantial changes. Even if buildings of 3 floors are still being erected in the region (mostly in the prefecture of Athens and Piraeus), constructions of 4 or more levels were decreasing. This observation becomes interesting when combined with the evident increase of buildings of 1 or 2 floors. Compact high buildings are being replaced by low-level ones in peripheral and suburban areas of the central city, meaning that the city is expanding through diffused and intermediate residential density characteristics. In other words, the evolution of the building activity of the last few years evidences the abandonment of compact growth and the strengthening of sprawl patterns (Couch et al., 2007).

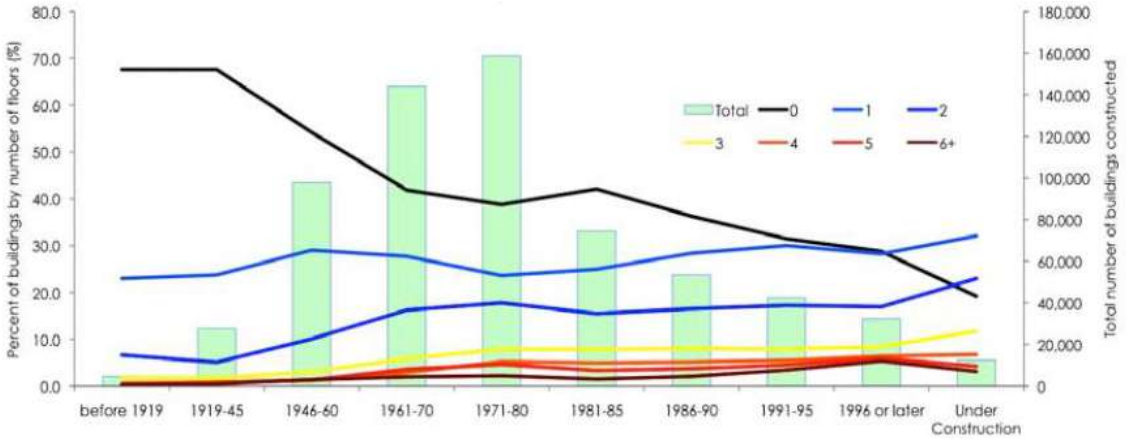


Figure 4.7. Number of buildings constructed by time period and percent of buildings by number of floors and by period of construction.

Even if the sprawl process in terms of per capita land-use is not particularly frightening in Attica (peripheral and suburban areas are sprawling with intermediate residential densities of 500 to 1,000 inhabitants per km^2), the transformation of the region's landscape arises major concerns (Economidou, 1993). The spatial outcomes of dispersed urbanization in Attica are clearly outlined considering a land imperviousness indicator, namely the per-capita amount of sealed land (m^2). Land imperviousness was distributed heterogeneously across the metropolitan region of Athens, evidencing not only a clear urban-rural gradient but also local processes of sprawl based on place-specific drivers (Figure 4.8).

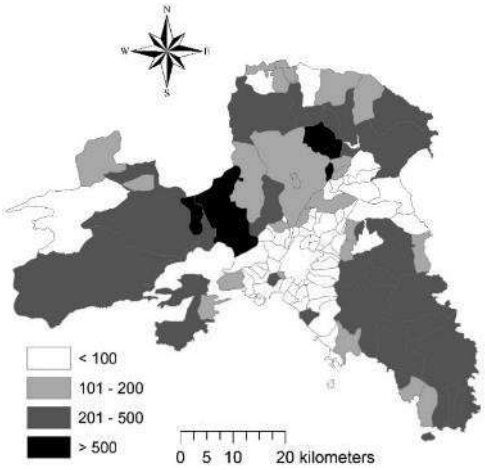


Figure 4.8. Per-capita sealed land (m^2) by municipality in Attica based on the European soil sealing map, 2006.

4.1.3. A visual analysis of fringe landscapes

A visual approach for localizing compact and sprawling urban areas was finally performed through the analysis of transformations in metropolitan fringes. If the urban fringe of a city is easy to define, then the considered city presents compact features. Conversely, if the urban fringe is hard to point out, then the city is probably developing sprawl patterns. This simple method for the assessment of compact and sprawling areas can be easily carried out with the help of tools freely available on the web such as those provided by Google Earth. Here below are presented a few images illustrating the urban fringe of compact and sprawling areas in Attica (Figure 4.9). Where it has been possible, a white line has been drawn on the satellite image to evidence the urban fringe. Where this has not been possible, a white circle has been drawn to represent the impossibility of defining the precise boundary of the city. This qualitative analysis on the characteristics of greater Athens' urban fringe has highlighted important characteristics of the sprawl process in Attica, namely spatial direction and intensity of development.

Satellite images have revealed a compact urban growth to the very maximum extent allowed by the morphological characteristics of the territory. In other words, the compact city center has grown right up to the borders of Mount Hymettus, Mount Egaleo and the occidental sea coast of Attica. Consequently, since the moment that the growth of the city center reached the maximum limit in the North West, South East and South West directions, greater Athens has begun to develop towards the North and North East and on the other sides of the two Mounts Hymettus and Egaleo. Sprawl is occurring exactly in those directions, and the first signs of this phenomenon are the undefined urban fringes forming towards the North of greater Athens and on the "external sides" of Mount Hymettus (in the Messoghia plain) and Mount Aegaleo (bordering Thriasio plain).

Figure 4.9. Visual analysis of compact and sprawled urban morphologies in Attica (left: eastern fringe between greater Athens and Hymettus/Penteli mounts evidencing Messoghia dispersed settlements; middle: northern fringe between greater Athens and Parnitha mount, evidencing Acharnes dispersed settlements; right: western fringe between greater Athens and Egaleo mount, evidencing Thriasio dispersed settlements).

4.1.4. The ambiguous role of planning

A relevant characteristic of the Mediterranean city - particularly evident in Athens - was the unplanned mode of its expansion. Faced with the difficulties in organizing territorial development, the concept of urban management appeared in Greece in the 1940s with the figure of K. Doxiadis. The famous Greek architect, author of the notion of 'Ekistics', defined the guidelines of a correct organization of territorial development that have been later adopted in the production of the urban plan of Attica (Delladetsima, 2012). The first territorial plans of Attica appeared in 1974 with the return of Democracy after the end of dictatorship in Greece. Only one year later, the concept of territorial management was included in the 1975 Constitution, article 24: "the reconstruction of the country from the point of view of territorial management and the control of the spatial development of cities and towns is under the direction of the State, for the objective of guaranteeing the quality of life and correct functioning of urban areas".

The master plan subsequently adopted was based on the logic proposed by P. Vassiliadis of "spaces within cities". In this sense, urban plans of Attica have greatly differed from the initial ones of the 1970s, since the territorial and demographic framework of the region have drastically changed. For this reason, the objectives and strategies of the first urban plans have been rethought and organized in the following years (Chorianopoulos et al., 2010). Probably the best example of the progressive adaptation of urban plans to the new necessities of the territory is the case of the Green belts plan in Attica. This plan was issued in 1995 and modified in the following years, with the objective of creating a green-belt around greater Athens and protecting valuable natural areas of the region (Figure 4.10). The failure of these plans results evident by observing the present landscape of Attica. The point that is worth stressing here is that sprawl in Attica is proceeding without taking into consideration the limits and guidelines imposed by the various urban plans of the region (Ferrara et al., 2015).

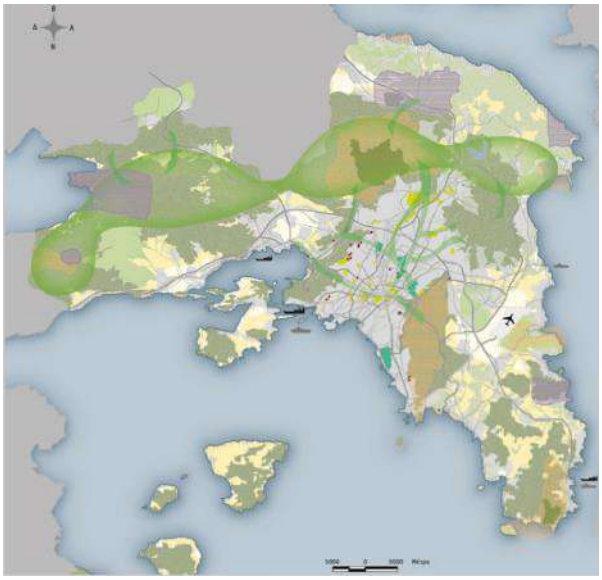


Figure 4.10. The Green Belt surrounding Athens illustrated in recent planning documents (2009).

The objectives of the first urban plans and of the subsequent program of Protection of the Environment of Athens Region was to ensure the functioning of urban agglomerations necessary for guaranteeing an acceptable quality of life for the population of the region. However, the urban development of Attica has been characterized by episodes of illegal urbanization followed by legalization acts. By "legally accepting" informal buildings, the Greek government has fueled the typical un-planned spontaneous development of Mediterranean cities. As a result, very often urban plans in Attica have acted more as general "guidelines" rather than effective legal tools (Economidou, 1993).

In order to give a sign of containment of illegal building activities, in turn contrasting the deterioration of living conditions in the urban centers of Attica, the Hellenic Ministry for the Environment Physical Planning and Public Works issued the "SOS Attiki" plan in June 1994. For the first time an official document of the Hellenic Government admitted that Athens was passing through a moment of profound crisis, recognizing that the absence of a strong town plan and planning organization has been the driving force of an uncontrolled urban development that has led the city to an undefined metropolitan structure. The major concerns expressed in that plan were: (i) atmospheric pollution; (ii) traffic congestion and inadequate transport infrastructure; (iii) aesthetics of the city, deteriorated by anarchical construction activities; (iv) scarcity of social and cultural services and green urban spaces; (v) deteriorating conditions of illegal neighborhoods; and, finally, (vi) social segregation.

Special attention has been given to the following four themes: economy, infrastructure, housing and landscape. The objectives expressed by each partial strategy have been resumed as follows: (i) specific programs for tertiary installations in old productive zones, (ii) creation of business-technology-research parks with the specific implementation of older industrial complexes, (iii) organization and urban upgrading of manufacture and industrial parks; and, finally, (iv) spatial redistribution and organization of whole-sale trade zones. The Plan aims at the creation of a non-polluting, multi-functional city, characterized by small distances, sensible growth, containment and the urbanization of the hinterland and a well-situated planning of future development. The reorganization of the urban inter-city transportation system with special emphasis on supporting man-transportation means, and particularly means with clean technologies (i.e. metro, tram and suburban train), includes the upgrade of the energy and telecommunications infrastructure and the completion of the sanitary installations that covers the increasing urban demand (Chorianopoulos et al., 2010).

Urban informality takes advantage of inefficient planning systems to transform peri-urban landscapes. In a place like Attica, characterized by extreme weather conditions during the summer season (heat waves, strong hot blowing winds from south and low humidity values) and a land cadaster that lacks a correct register of forest areas, woodlands and un-protected forests represent convenient areas for the diffusion of illegal urbanization (Weber et al., 2005). Furthermore, construction in Greece can only be carried out on land classified as cultivable, therefore, a leveling off of the terrain by fire plays right into the hands of the developers. Spontaneous settlements, later included in the land cadaster through official condones, represent the trigger to sprawl mechanisms in these areas (Nikolakopoulos et al., 2005). The relationship between urbanization and fire activities on the urban fringe and peripheral zones of greater Athens appears evident. Housing cooperatives and private enterprises are the ones that are taking the biggest advantage from wildfire activities

and inefficient land cadaster registers to urbanize more land. Wildfires have been often used as the means for "preparing" the natural area to future urbanization (Biasi et al., 2015). The Greek authorities are trying to control the phenomenon through regional plans of protected natural areas, but recent statistical data suggests that the phenomenon is far from being controlled.

The convergence of southern European countries towards structural policies for the environment have given rise to a 'cultural transition' that has been expressed, for example, in the initiatives of Local Agenda 21. However, many issues still remain open including the rapid loss of agricultural land and semi-natural, high-value ecological landscapes, soil deterioration and desertification, regional climate change, just to provide key examples (Marull and Mallarach, 2005). The promotion of a common environmental framework in the Mediterranean region has to reconcile the different approaches adopted across the different areas along the northern Mediterranean arc, with priority interventions related to the transport sector, air pollution, waste management and urban regeneration, and the southern Mediterranean arc, needing urgent development policies together within an overall strategy dealing with the stabilization of migration flows (Marull et al., 2009; Cassier and Kesteloot, 2012; Tombolini and Salvati, 2014; Cuadrado-Ciuraneta et al., 2017).

Ambitious goals could be achieved in the construction of a common platform for management of coastal areas and peri-urban regions as well as for the promotion of a multi-functional agriculture that acts as a brake to urban sprawl and to the deterioration of cultural landscapes (Christopoulou et al., 2007). Networking, exchange of experiences and expertise, sharing common objectives, appear valuable tools in the management of specific problems, such as the development of illegal suburbs, waste management or the recovery of abandoned industrial spaces (Mavrakis et al., 2015). A new notion for 'Mediterranean urbanities' can be expressed in the convergence of urban policies that contribute jointly to the quality of architecture, urban spaces and natural environments (e.g. Delfanti et al., 2016). In this direction, only multi-dimensional planning strategies will effectively contribute to the development of southern European cities after a time of economic crisis.

4.2. The evolving spatial distribution of cropland

Rural areas and the related cropping systems play an important role in ecosystem services, improving quality of metropolitan environments (Duvernoy et al., 2018; Pili et al., 2017; Sanesi et al., 2017; Zambon et al., 2018). Despite the importance of cropland in peri-urban contexts, a progressive reduction in size, production, and functionality has been observed in representative metropolitan regions because of urban spillover (Chas-Amil et al., 2013; Zipperer et al., 2012). Wildland-urban interfaces are particularly vulnerable to cropland decline and physical degradation because of the increasing anthropogenic pressure (Carlucci et al., 2017; Munafò et al., 2013; Salvati, 2013). In Mediterranean Europe, interfaces are particularly rich in animal and plant biodiversity, as well as historical and cultural heritage, being constituted by heterogeneous peri-urban areas with mixed human settlements of different ages and natural-agricultural habitats forming a diversified landscape mosaic (Antrop, 2004; Salvati et al., 2018; Zambon et al., 2018). Reflecting unsustainable use of land, rural-urban migration, abandonment of cropland, and land marginalization, urban expansion is probably the most impacting factor on cropland, determining landscape transformations and fragmentation of non-urban land use types (Pili et al., 2017; Colantoni et al., 2016; Salvati et al., 2013). Moreover, land use modifications of fringe land may severely impact cropland, resulting in forest, shrubland, and pasture expansion, due to spontaneous or human-driven processes of re-naturalization (Barbati et al., 2013; Colantoni et al., 2015). However, the main socioeconomic forces at the base of landscape transformations and the underlying mechanisms linking local communities with specific environmental characteristics of rural areas are mostly underrepresented in the Mediterranean basin and still need specific investigation covering both socioeconomic and biophysical issues (Salvati et al., 2008; Ferrara et al., 2014; Serra et al., 2014; Karamesouti et al., 2015).

Cited article

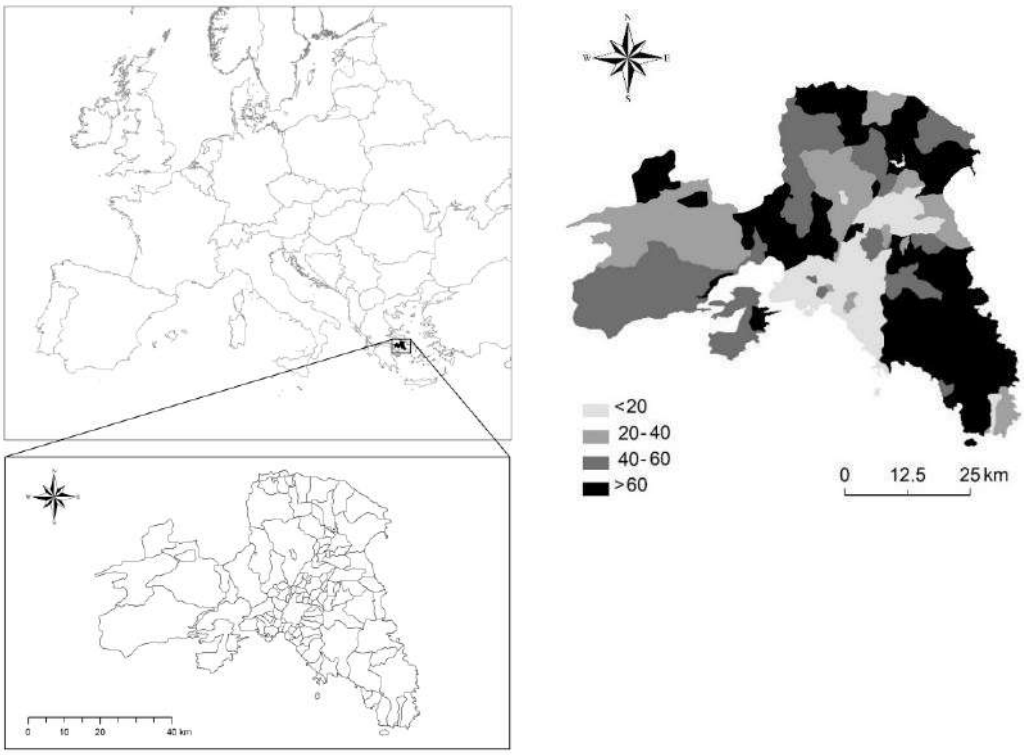
Colantoni, A., Zambon, I., Gras, M., Mosconi, E. M., Stefanoni, A., Salvati, L. (2018). Clustering Or Scattering? The Spatial Distribution Of Cropland In A Metropolitan Region, 1960–2010. Sustainability, 10(7), 1-12.

In such dynamic contexts, identifying relevant factors (and understanding the underlying processes) that drive changes in the use of land is key to sustainable management of fringe land (Duvernoy et al., 2018; Pili et al., 2017). Despite indicators of land take having been extensively developed in recent times (Hasse and Lathrop, 2003), only a few studies have analyzed complex interactions between land use and transformations of fringe land driven by urbanization (Duvernoy et al., 2018; Salvati et al., 2018; Colantoni et al., 2016; Catalán et al., 2008; Cuadrado-Ciuraneta et al., 2017). Based on these premises, this article illustrates a comprehensive analysis of cropland distribution over space in a Mediterranean European region (Athens, Greece) from 1960 to 2010. Athens is considered a representative case of (rapidly expanding) Mediterranean cities with a typical monocentric organization and more recent processes of urban sprawl into traditional rural areas (Zambon et al., 2017). By adopting a multivariate strategy to analyze multi-domain indicators of urban expansion (Zambon et al., 2018), the study identifies clustering or scattering patterns in the spatial distribution of cropland, and the most relevant factors involved in such trends, as a contribution to sustainable land management in expanding metropolitan regions of advanced countries.

4.2.1. Land use analysis in a metropolitan region

Focusing always in the Athens metropolitan region, from 1951 to 2011, population density increased by about 2900 inhabitants/ km² with a more balanced settlement distribution over space and the formation of growing poles outside the consolidated city (Rontos et al., 2016). After World War II, Athens and Piraeus expanded as the main urban poles thanks to the concentration of service activities (Athens) and industrial functions (Piraeus) (Zambon et al., 2018; Chorianopoulos et al., 2010). Since the early 1990s, the Greater Athens area experienced a process of urban de-concentration, with expansion of discontinuous fringe settlements (Duvernoy et al., 2018; Chorianopoulos et al., 2014). The development of new urban cores was observed (Couch et al., 2007; Perdigao and Christensen, 2000; EEA, 2006) in Messoghia (a region centered in the municipalities of Markopoulo Messoghias, and Spata), which is considered the largest sprawling area in Attica (Perdigao and Christensen, 2000), and in the Athens north-east district centered in the municipalities of Maroussi and Kifissià, where urban development driven by the 2004 Olympic Games resulted in extensive soil sealing and an increased rate of land consumption (Di Feliciantonio and Salvati, 2015).

The percent share of cropland in total municipal area, taken as the dependent variable in this study, was derived from aggregate data of (i) a land use census held by the Greek Statistical Institute for the years 1960, 1970, 1980, 1990, and 2000; and (ii) Urban Atlas (UA) database referring to 2010. According to Salvati et al. (2018), the accuracy of the collected data was evaluated by comparison with additional data sources that provide an independent estimate of cropland expansion (or decline) at a fine grained spatial scale in the study area: (i) a soil map produced by the Institute of Geology and Soil Chemistry (Piraeus) delimitating the Athens urban area for 1948; (ii) the LaCoast (LC) project database mapping land use in coastal regions of Europe for 1975 (EEA, 2006); (iii) Corine Land Cover (CLC) maps referring to 1990 and 2000 (EEA, 2010; Salvati, 2014); (iv) the pan-European GlobCorine map referring to 2009 (Carrus et al., 2015); and (v) prefecture-level data on cropland derived from the Greek National Census of Agriculture for 1961, 1970, 1980, 1990, 1999, and 2009.



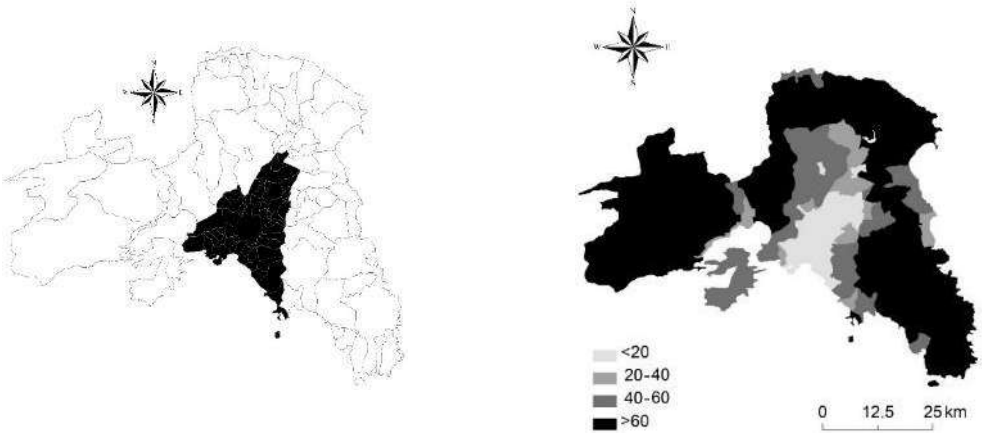


Figure 4.11. Municipal boundaries in the Athens metropolitan region (a), its position in Europe (b), and classification of the Athens region in urban (black and rural (white) municipalities (c); percent share of cropland in total municipal area by year and municipality (1960: (d); 2010: (e)).

A total of 11 variables describing population dynamics, topography, urban structure, competing land use (i.e., forest), and climate and soil quality were considered additional context variables in this study and were derived from official statistics (various data sources) at the municipal scale (Table 4.3). According to Salvati and Serra (2016), these variables were considered with the aim to provide a comprehensive assessment of the socioeconomic and territorial characteristics of municipalities in the study area, with a possible (direct or indirect) impact on cropland growth or decline. Following a previous study by Tomao et al. (2017), these variables were adopted in regression analysis as predictors of the spatial distribution of cropland over a temporal period spanning from the early 1960s to the early 2010s.

Aggregate data on resident populations (municipal scale) were derived from the National Census of Population carried out by the National Statistical Service of Greece (NSSG) at each decade (1961, 1971, 1981, 1991, 2001, and 2011) and were used to calculate per capita built-up area at the same spatial scale (Urb). Urb was considered an indicator of urban land-use efficiency. Population growth (annual percent rate) was considered a proxy of urban expansion (Zitti et al., 2015). Topographic and territorial variables include specific descriptors of landscape and urban structure (average elevation, proximity to the sea coast, municipal area, and distance to key urban nodes such as Athens, Piraeus, Maroussi, and Markopoulo Messoghias). Topographic variables were measured using ArcGIS software (ESRI Inc., Redwoods, CA, USA). Two variables describing quality of soil and climate were also calculated from a specific dataset released by the European Environment Agency (Colantoni et al., 2016). Soil and climate quality were evaluated with the final aim to ascertain the specific contribution to local-scale land suitability to agriculture (Salvati et al., 2012). Data on forest areas were derived from computation on land use census for the years 1960, 1970, 1980, 1990, and 2000 and Urban Atlas (UA) map referring to 2010 (Tomao et al., 2017).

Table 4.3. List of variables considered in the present study (percent share of cropland in total municipal area is the dependent variable in regression models).

Acronym	Variable	Measurement Unit	Source	Time Interval
Agr	Share of cropland in total municipal area	%	Census of land-use	1960-2010
For	Share of forests in total municipal area			
Gro	Annual population growth rate		Census of population	1961-2011

Area	Municipal surface area	km^2	Territorial statistics	1960-2010
Urb	Per capita built-up area	m^2	Census of land-use	"
Ele	Average municipal elevation	M	Census of population	Once per time
Sea	Proximity to the sea coast	0: internal; 1: coastal	Territorial statistics	"
dAth	Distance from Athens	Km	Own elaboration	"
dPir	Distance from Piraeus	"	"	"
dMar	Distance from Maroussi	"	"	"
dMak	Distance from Markopoulo M.	"	"	"
Cqi	Climate quality index	0-1	Europ. Env. Agency	"
Sqi	Soil quality index	"	"	"

Data analysis was organized in two steps: (i) exploratory analysis, based on univariate and multivariate approaches, with the objective to analyze long-term changes (50 years) in the spatial distribution of cropland in the study area and (ii) regression models, investigating medium-term changes (10 years) in cropland expansion (or decline) and identifying the main forces at the base of such transformations. Descriptive statistics (including average and median, coefficient of variation, maximum value, coefficient of variation, kurtosis, and asymmetry) describing the spatial distribution of the dependent variable in the municipalities belonging to the study area were calculated at the beginning (1960) and the end of the study period (2010). The relationship between the dependent variable and the linear distance from downtown Athens was illustrated using scatterplots at the same two time points and adapting a square goodness-of-fit polynomial curve to the observations (n = 114). A hierarchical clustering (using Ward's agglomeration rule based on a Euclidean distance matrix) was run for the same time points (1960 and 2010) with the aim to group separately (i) variables and (ii) municipalities of the study area on the basis of their similarity patterns (Salvati et al., 2012), thus allowing for the identification of specific territorial profiles associated with high and low levels of percent share of cropland in total municipal area (Salvati et al., 2011). Based on descriptive and multivariate techniques, a statistical analysis run on aggregate data at the beginning and the end of a long enough time period-as in the present study-may provide an enhanced interpretation of metropolitan transformations with impact on land use distribution (Salvati, 2014).

A multiple linear regression analysis based on ordinary least square estimation was finally performed for each time point (1960, 1970, 1980, 1990, 2000, 2010) with Agr as the dependent variable and the 11 predictors reported in Table 4.3. By using a forward stepwise approach for the selection of un-correlated predictors, this analysis allowed for the identification of changes in the most relevant factors associated with cropland dynamics over time, ranking the individual predictors based on their (direct or indirect) influence on cropland distribution over space and reducing the overall redundancy in the multivariate dataset (Salvati and Serra, 2016). All variables were standardized prior to regression analysis. Significant variables were selected fixing F-to-remove and F-to-enter thresholds equal to 3 and 1.5, respectively. Adjusted R2 was calculated separately for each regression to assess the overall goodness-of-fit of each selected model. Moreover, a Fisher-Snedecor F test with $p < 0.001$ was also run to verify significance against the null hypothesis of a non-significant model. A Durbin-Watson statistic was applied separately to the residuals from the six least squares regressions, testing for serial correlation in the residuals. Values of Durbin-Watson statistics close to 2 (e.g., in the range between 1.5 and 2.5) indicate negligible auto-correlation.

4.2.2. Analyzing the spatial distribution of cropland (1960-2010)

Descriptive statistics and maps showing the spatio-temporal evolution of the dependent variable (percent share of cropland in total municipal area) are reported in Figure 4.12 and Table 4.4, considering municipalities as the elementary spatial domain. Descriptive statistics outline a moderate increase in cropland surface from 1960 to 2010 (from 37% to 39% on average). Median and average values are rather similar and indicate a substantial regularity in the distribution of the dependent variable over time (Table 4.4), with a spatial variability decreasing between 1960 and 2010. The maximum value of the dependent variable was decreasing slightly (96% in 1960 and 87% in 2010), although the percent share of municipalities with cropland in total municipalities increased from 84% (1960) to 87% (2010).

Table 4.4. Descriptive statistics of percent share of cropland in total municipal area by year.

Statistic	1960	2010
Average	36.9	38.6
Median	35.2	40.3
Median to average	0.96	1.04
Coefficient of variation	0.86	0.80
Maximum value	96.0	88.6
Municipalities with cropland (%)	83.6	87.0
Asymmetry	0.27	0.09
Kurtosis	−1.39	−1.47

Moderate increases or decreases at a local scale are more likely driven by place-specific socioeconomic factors and/or biophysical conditions. Agricultural areas constituted a buffer to urban expansion, competing with forest land use in more remote places of the metropolitan region. The rural municipalities with the largest cropland surfaces are those situated in traditional agricultural districts such as Megara, Thriasio, Messoghia, and Marathon. Such trends highlight complex transformations of the peri-urban Athens landscape in the last 50 years. The relationship between cropland area and distance from downtown was non-linear, with the highest values observed at a distance ranging between 30 km and 40 km from downtown Athens. The goodness-of-fit of this relationship improved significantly over time, indicating an increased urban-rural polarization at the end of the study period (Figure 4.12). Only a few municipalities experienced values of the study variable less than 10%, suggesting that cropland is a rather ubiquitous land use not only in rural districts but also in peri-urban marginal areas.

Cluster analysis identified a distinctive similarity pattern for the contextual variables at the beginning and the end of the study period. Cropland clustered together with the distance from all the urban nodes considered in this work (Athens, Piraeus, Maroussi, Markopoulo M.) for 1960, indicating a monocentric structure typically oriented along the urban gradient. Considering 2010 data, cropland clustered together with per capita built-up area and distance from Athens, Piraeus, and Maroussi only. These results suggest a moderate departure from a monocentric structure, outlining instead a more complex spatial interplay between agriculture and low-density settlements that results in a mixed and heterogeneous fringe landscape. Consistently, municipalities in the study area were classified into homogeneous classes (Figure 4.13) grouping (i) urban municipalities (left side of each graph)-primarily belonging to the Greater Athens area-and (ii) mixed peri-urban and rural municipalities (right side of each graph). Strictly rural municipalities, located over 30 km from

downtown Athens and with a share of cropland in total municipal area systematically over 50%, were grouped into a specific class (dashed circle, right side of each graph). Only minor differences in hierarchical clusters were detected for 1960 and 2010.

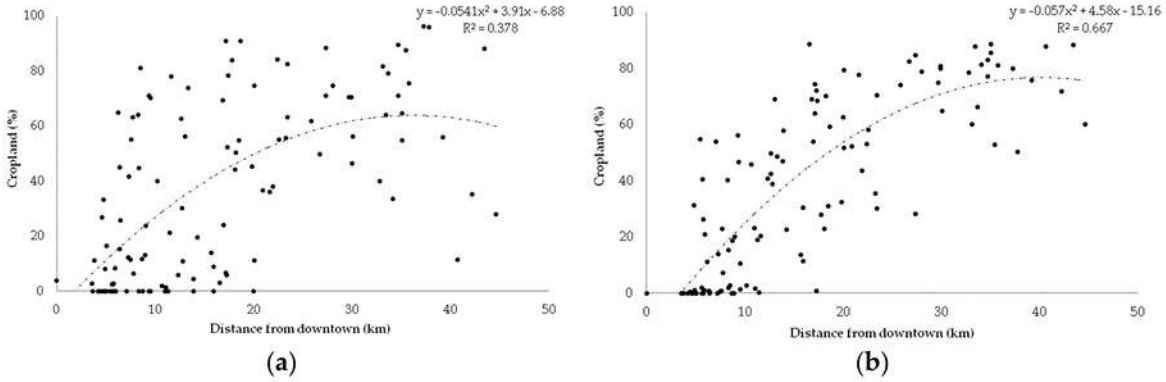


Figure 4.12. The relationship between percent share of cropland in total municipal area and the distance from downtown Athens (a): 1960; (b): 2010).

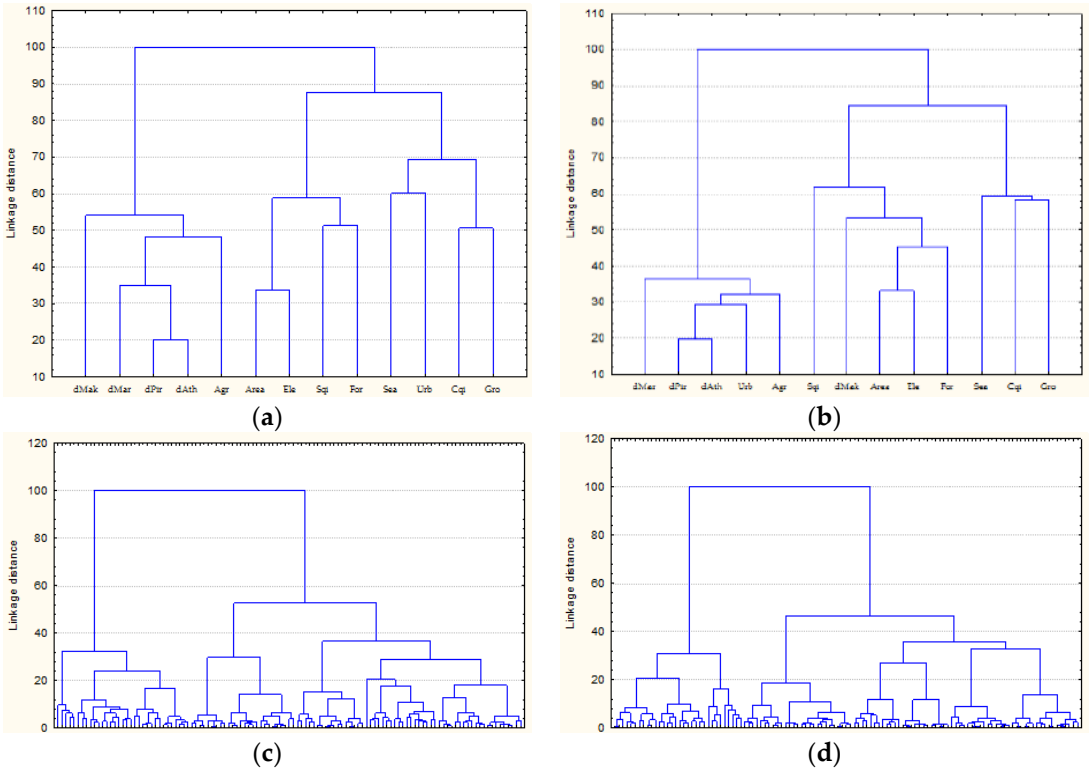


Figure 4.13. Hierarchical clustering of variables (a) and municipalities (b) in the study area ((left): 1960, (right): 2010); dotted circles indicate strictly urban municipalities (c) and mixed peri-urban/rural municipalities (d).

Forward stepwise multiple regression (Table 4.5) identified (and ranked the impact of) the most relevant predictors influencing the dependent variable (Agr) at each time point investigated in this work. The model's goodness-of-fit increased over time, reaching a particularly high adjusted R2 (0.75) for 2010. Cropland area increased with the distance from downtown Athens for the whole time period investigated in this study. However, the impact of this predictor was largely variable

over time, being the highest in 1960 and decreasing progressively in the following decades thanks to emerging suburbanization processes. A new increase of the regression coefficients was observed for the early 1990s in parallel with a period of huge urban expansion and a final moderate decrease was observed for the early 2010s. The distance from Piraeus explained some of the additional variance observed in selected models and may indicate the period of maximum consolidation of the monocentric model (1970, 1980). The spatial relationship between forests and cropland was negative and significant only for the first decades under investigation (1960, 1970, 1980). Lower regression coefficients indicate a progressive reduction in land use competition between forests and cropland, because of the huge decline of forests in the study area. Population growth rate was positively associated with cropland since the early 1990s; this result is reflected in fringe landscapes where expanding settlements and cropping systems frequently coexist. Distance from Markopoulo Messoghias was negatively associated with the dependent variable for 1970 and 1980, indicating the period of maximum expansion of cropland in a traditional rural district such as Messoghia. Suburbanization-driven landscape transformations in a period immediately following the 1980s may explain the non-significant impact of this predictor in the following decades. Distance from Maroussi (the modern business district of Athens, expanding with the Olympic Games) was relatively less important and significant only for the 1960 and 2000 models. Climate quality had a role in explaining a high level of cropland at the municipal scale only in specific years (1960, 1990, 2000). Soil quality was associated with a higher level of cropland in the last two decades (2000, 2010). Finally, municipal size was occasionally associated with cropland area, significantly impacting the dependent variable only for 1970 and 1980.

Table 4.5. Results of forward stepwise multiple regressions with percent share of cropland in total municipal area as the dependent variable.

Variable	Beta	Std. Error	*t*-Statistic	*p*-Level
1960: Adj-R^2 = 0.590, $F_{(5,109)}$ = 33.9, $p < 0.001$; D-W test = 1.87				
dAth	1.302	0.135	9.6	0.000
For	−0.497	0.071	−7.0	0.000
dMar	−0.603	0.128	−4.7	0.000
Cqi	0.155	0.065	2.4	0.018
Urb	−0.128	0.062	−2.1	0.042
1970: Adj-R^2 = 0.594, $F_{(6,108)}$ = 28.8, $p < 0.001$; D-W test = 1.74				
dAth	0.418	0.163	2.6	0.012
For	−0.467	0.070	−6.7	0.000
dPir	0.507	0.151	3.4	0.001
Area	0.157	0.072	2.2	0.031
dMak	−0.165	0.075	−2.2	0.030
Urb	−0.134	0.066	−2.0	0.044
1980: Adj-R^2 = 0.546, $F_{(5,109)}$ = 28.4, $p < 0.001$; D-W test = 1.64				
dAth	0.396	0.171	2.3	0.022
For	−0.374	0.074	−5.1	0.000
dPir	0.410	0.158	2.6	0.011
Area	0.219	0.076	2.9	0.005
dMak	−0.144	0.078	−1.9	0.050
1990: Adj-R^2 = 0.656, $F_{(3,111)}$ = 73.5 $p < 0.001$, D-W test = 1.92				
dAth	0.743	0.060	12.5	0.000
Gro	0.204	0.059	3.5	0.001
Cqi	0.136	0.056	2.4	0.017

2000: Adj-R^2 = 0.693, $F_{(5,109)}$ = 52.6, $p < 0.001$; D-W test = 2.05				
dAth	0.980	0.116	8.4	0.000
Gro	0.155	0.060	2.6	0.011
Sqi	0.167	0.055	3.1	0.003
Cqi	0.113	0.054	2.1	0.041
dMar	−0.226	0.111	−2.0	0.044
2010: Adj-R^2 = 0.749, $F_{(4,110)}$ = 86.0, $p < 0.001$; D-W test = 2.00				
dAth	0.565	0.080	7.1	0.000
Sqi	0.305	0.048	6.3	0.000
Gro	0.251	0.048	5.2	0.000
Urb	0.272	0.080	3.4	0.001

4.2.3. Clustering or scattering?

The study proposes an integrated analysis of cropland distribution over space and land use changes in a metropolitan region, providing a relevant knowledge base with implications for urban studies, agricultural policy, and regional planning (Perrin et al., 2018; Moreira et al., 2011; Radeloff et al., 2005; Dobbs et al., 2014). Specific socioeconomic and biophysical factors influencing cropland distribution have been identified through an original procedure based on multivariate exploratory statistics (Pili et al., 2017; Sanesi et al., 2017; Zambon et al., 2018). Despite massive urban expansion, results showed a moderate (and spatially-heterogeneous) increase in cropland over time, mainly at the expenses of forest areas (Mather, 2004; Frenkel, 2004; Koutsias et al., 2010). Fringe landscapes became more heterogeneous and mixed, reflecting a latent interplay between low-density settlements and medium-small farms specialized in tree and garden crops (Salvati et al., 2013). Cropland constituted a relevant part of fringe land, and its transformations have a direct impact on the structure of natural-based infrastructures surrounding Athens.

Earlier studies have clearly evidenced how suburbanization has negatively affected the structure of landscapes, reducing the overall environmental quality of the region (Zomeni et al., 2008). An increasing polarization in fringe mixed areas and more remote districts was observed during the investigated time period. The monocentric model typical of the study area has influenced markedly the spatial distribution of cropland, evidencing the importance of traditional agricultural systems as a latent urban-forest interface (Novara et al., 2017). At the same time, urban sprawl impacted cropland directly by fragmenting agricultural utilized area and partly disconnecting pristine agricultural-natural districts. Various forms of infrastructure (including the Athens International Airport built-up in the traditional agricultural district of Messoghia) were also important in this process.

As far as factors associated with changes in land use are concerned (Colantoni et al., 2016), the results from the multivariate analysis allow for the evaluation of where, when, and how increasing complexity occurred in Athens' landscape over time. Basically, the distance from downtown Athens remained one of the most relevant predictors of the spatial distribution of cropland in the study area. Considering the spatial legacy of a compact and monocentric urban form-only partly altered by recent suburbanization-Athens is a representative example for other European cities experiencing similar development patterns (Catalán et al., 2008).

In these regards, the study clarifies the relationship between land use and the local context (Delfanti et al., 2016; Kelly et al., 2015), identifying the variables most associated with cropland

(Kosmas et al., 2016). The significance of the empirical findings of this study for future land use decisions within the local context (considering current economic, political, and soil/climate trends) lies exactly in this issue. Results confirm that the Athens metropolitan region is sensitive to environmental degradation (Salvati and Zitti, 2005) because of the progressive urbanization of rural fringe (Salvati et al., 2012). This suggests the role of multi-scalar sustainable land management policies (Monarca et al., 2012; Monarca et al., 2011; Monarca et al., 2008; Boubaker et al., 2016; Pari et al., 2015; Carlini et al., 2017) in reducing the impact of urban sprawl on cropland (Colantoni et al., 2016; Salvati et al., 2008; Zambon et al., 2017). At the same time, a more effective protection of traditional agriculture is required, especially for rural and remote districts (Ceccarelli et al., 2014). Although the study may represent a good reference either in methodological and results direction for further appraisal of the investigated approach in other European contexts, further studies are required to provide a better understanding of biophysical drivers that are not directly considered in this study, such as wildfires. Moreover, the adopted variables could be integrated with some additional economic indicators, especially related to the regional agriculture system and related market relations. An extensive investigation of methodological limitations and potential sources of error considering the selected indicators and omitted variables is also relevant to advance landscape and regional studies. In this regard, a specific approach based on spatially-explicit models (e.g., considering spatial autocorrelation) is a possible solution for overcoming the implicit problems related with geographical data. Finally, considerable efforts are still needed to design tools capable of guiding decision makers towards the sustainable use of land (Kazemzadeh-Zow et al., 2017). Identification and long-term monitoring of urban-cropland interfaces is the basis for a more effective strategy of sustainable land management and planning.

4.3. Urban growth and peri-urban agriculture

Urbanization has recently transformed agricultural areas into mixed spaces characterized by landscape fragmentation and a typically peri-urban socioeconomic context (Van Eetvelde and Antrop, 2004; Serra et al., 2014; Cuadrado-Ciuraneta et al., 2017). Especially discontinuous urbanization has been frequently associated to convoluted landscape structures and rapidly-evolving socioeconomic structures (Vanier, 2007; Roux and Vanier, 2008; Pili et al., 2017). In this line of thinking, recent studies have promoted a comprehensive understanding of socioeconomic dynamics in peri-urban spaces (Allen, 2003; Barbati et al., 2013; Colantoni et al., 2016), demonstrating that urban sprawl has influenced land-use patterns and social organization of rural societies around cities (Busch et al., 2006; Salvati and Gargiulo Morelli, 2014; Serra et al., 2017).

The 'peri-urbanization' notion involves a series of socioeconomic processes characteristic of fringe districts in the immediate surroundings of central cities. It is widely recognized how peri-urbanization has progressively altered contemporary rural landscapes, negatively influencing ecosystem processes and services, fragmenting or depleting traditional farming systems, modifying land value and reducing social cohesion of local communities (Munton, 2009; Gant et al., 2011; Pastur et al., 2012; Recanatesi et al., 2016). Having expanded in a context of mono-centric urban growth (Bonnin-Oliveira, 2012), French metropolitan regions have been often characterized as representative cases of 'peri-urbanization' in Western Europe (Jaillet, 2004; Roux and Vanier, 2008).

Cited article

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Farming spaces have been progressively transformed in continuous and discontinuous urban fabric with the uneven development of infrastructures and settlements (Verspecht et al., 2005; Hailu and Brown, 2007; Hewitt and Hernandez-Jimenez, 2010). These socioeconomic dynamics have confined farms to peripheral land especially in metropolitan regions experiencing a rapid increase in population density, unregulated urban expansion and uneven loss of fertile soils (European Environment Agency, 2006). However, agriculture in peri-urban districts contributes to sustainable development of those areas, containing urban expansion, providing ecosystem services, facilitating social inclusion and consolidating the food security of the local communities (Antrop, 2004; Busch et al., 2006; Biasi et al., 2015; Opitz et al., 2016). With this perspective in mind, peri-urban farming became a key issue for the European Commission since the late 1990s. A dialogue between urban and rural stakeholders focusing on the functioning of socio-environmental systems, becomes crucial (Duvernoy et al., 2005; Vejre et al., 2007; Overbeek, 2009; Zasada, 2011; Duvernoy, 2016).

Farming systems are continuously changing in European peri-urban fringes (Rothwell et al., 2015) and planning strategies specifically designed for a sustainable development of the urban-rural interface have been proposed in an increasing number of cities (Bouraoui, 2005; Catalán et al., 2008; Perrin, 2013; Bonnefoy and Brand, 2014; Duvernoy, 2016; Soulard et al., 2017). Regional planning has sometimes demonstrated to provide poorly-effective responses and solutions to regional disparities driven by specific processes, such as peri-urbanization (Bertrand et al., 2006). In this perspective, conflicts between uses of land can be only managed with a comprehensive knowledge

of the intimate behaviour of economic agents (e.g. Kelly et al., 2015), including farmers (Abrantes et al., 2010).

An increasing interest on the role of individual farmers as actors of socioeconomic transformation of peri-urban spaces has emerged since the mid-1970s in wealthier countries, and especially in Europe (Bryant, 1995). Part of these actors have reoriented their activities towards multifunctional farming (Meert et al., 2005; Wilson, 2007) to adapt to peri-urban constraints and opportunities (Zasada, 2011). Nevertheless, a correct design of territorial strategies for management and planning of peri-urban areas become crucial in rapidly-changing socioeconomic contexts, while latent interplays between local governance, economic development and sustainable land management are particularly difficult to investigate in mixed urban-rural contexts (Davoudi and Stead, 2007; Galli et al., 2010).

Based on the understanding that urban societies partly depend on functions and services provided by surrounding peri-urban agriculture (Overbeek, 2009; Vejre et al., 2007; Zasada, 2011; Opitz et al., 2016; Rothwell et al., 2015; Salvati et al., 2016), a comprehensive understanding of peri-urban farming and its changes over time and space are increasingly required to inform sustainable land management strategies. The study with Duvernoy et al. (2018) contributes to this deserving issue by analyzing long-term dynamics of peri-urban agriculture vis à vis urban expansion (1988-2010) in Toulouse, the fourth city in France, using two complementary research approaches. Under the hypothesis that socioeconomic attributes are relevant to identify land-use conflicts characterizing peri-urbanization processes, the first approach adopted is eminently quantitative and evaluates together environmental, economic and social indicators profiling agricultural systems, connecting different types of urban development to (evolving) peri-urban farm types (Salvati et al., 2016). The second approach builds on a qualitative survey on a sample of farms with the aim to investigate farming evolution strategies and the implications for peri-urban land-use (Inwood and Sharp, 2012).

4.3.1. Discovering agriculture in a post-industrial city

The study in Duvernoy et al. (2018) investigated urban development and peri-urban farming in Toulouse, the fourth largest metropolitan area in France, hosting nearly 1,2 million inhabitants, one third concentrated in the central municipality of Toulouse (Zaninetti, 2006). The analysis has examined the Functional Urban Area of Toulouse (FUA) whose boundaries were defined following the Large Urban Zone (LUZ) definition introduced by Eurostat. FUAs are functional economic units identified on the base of population density and include the "inner city" (a high-density cluster of adjacent grid cells of 1 km^2, at least 1,500 inhabitants per km^2) and a (more or less extended) "commuting zone", i.e. peri-urban ring. The French FUA equivalent (i.e. urban area) - defined according to a criterion oriented toward the central-place theory - was used.

A mixed research approach based on quali-quantitative techniques was proposed: (i) the quantitative methodology allows investigating agricultural trends and dynamics in the Toulouse's metropolitan area using indicators and an exploratory multivariate statistical analysis; and (ii) the qualitative approach is focused on arable crops' farmers with the aim to analyse their strategies of farm change in the metropolitan context.

A total of 27 indicators for each municipality of the Toulouse's metropolitan area were collected from official statistics (French agricultural censuses produced by the statistical service of the French Ministry of Agriculture) and referring to a time interval encompassing the last two decades from

1988 to 2010 (Table 4.6). Indicators allow delineating specific socioeconomic profiles of farmers (e.g. age, education, on-farm and off-farm multiple activities) and farms (average Utilized Agricultural Area, hereafter 'UAA', drained and irrigated cropland, seasonal job, permanent employees, holdings' successors) in each municipality of the metropolitan area.

Table 4.6. Agricultural indicators considered.

Variable	Time period
Less than 40 years-old farm-holders (% in total farmers)	2010
Less than 40 years-old farm-holders: change over time (% in total farmers)	2000- 2010
Farm rent: share in total UAA (%)	2010
Irrigated area (% in total UAA)	2010
Drained area (% in total UAA)	2010
Seasonal workers (% in total workforce)	2010
Permanent employees (% in total workforce)	2010
Farms with permanent employee: share of total (%)	2010
Livestock farms (%)	1988, 2000, 2010
Change over time in total UAA (%)	1988-2000, 2000-2010
Heads of operations and pluri-active farmers: share in total farmers (%)	2010
Share of arable land in the UAA (%)	2010
Farm-holders with higher education (%)	2010
Share of UAA of medium-large farms in total UAA (%)	2010
Large farms > 100 ha (%)	2010
Share of marginal farms in the UAA (%)	2010
Total farm-holders: change over time (%)	2000-2010
Share of agricultural area (UAA) of farms > 100 ha (%)	2010
Farms with agricultural area (UAA) > 100 ha (%)	2010
Individual holdings: share in the UAA (%)	2010
Farms UAA average (ha)	1988, 2000, 2010
UAA average by standard farm unit (ha)	2010
Individual holdings, share in the UAA	2000-2010
Average standard gross income: change over time (%)	2000-2010
Average standard gross income	2010
Holdings without known successor, share in the UAA (%)	2010
Holdings without known successor (%)	2010

Maps of selected indicators were realized with the aim to provide an overview of peri-urban farming geography in Toulouse (Triboulet, 2001). A Principal Component Analysis (PCA) was run on the collected data matrix to investigate multivariate relationships between indicators assessing farmers' profiles and farms' characteristics over time and space. PCA results allow exploring socioeconomic transformations, completing the outcomes of descriptive statistics (Salvati et al., 2013). The analysis aims at selecting latent components as a combination of the studied indicators, providing intrinsic information based on similarity and correlation patterns among the individual variables (Becagli et al., 2013). Results of the PCA are particularly relevant when a high number of moderately redundant variables is considered (Salvati and Carlucci, 2011), since the analysis extracts as much information as possible from the data matrix producing a smaller set of components generated as linear combination of the input variables (Salvati et al., 2014). Components with eigenvalues > 1 were identified and analyzed using the related component loadings (a coefficient ranging between 1 and -1 that indicates intensity and direction of the relationship between each component and input variable) and scores (a coefficient evaluating the association of each studied observation unit, the municipality, to each component).

A linear correlation analysis using Pearson product-moment coefficients was finally run to identify significant pair-wise relationships between each of the selected agricultural indicators and three attributes describing the spatial structure of Toulouse metropolitan region at the municipal scale (population density, distance from Toulouse municipality, average elevation). Population density was calculated dividing the absolute population size by the municipal size, which were used as control variables (Salvati and Carlucci, 2011). Pearson correlation coefficients range from 1 (positive correlation) to -1 (negative correlation). A null correlation coefficient indicates absence of linear correlation between two variables. Significant correlations were tested at $p < 0.05$ after Bonferroni's correction for multiple comparisons (Becagli et al., 2013).

A survey was conducted in 2011 interviewing a sample of 15 farmers operating in the study area (Duvernoy and Paradis, 2016), concentrated on farms producing cereals, oil and protein crops (wheat, durum wheat, corn, sunflower) since they constitute the dominant cropping system in the Toulouse metropolitan region (DRAAF Midi-Pyrénées, 2014), as well as in the whole of France (Ministère de l'Agriculture et de l'Agroalimentaire-SSP, 2012). This cropping system presents several features reflecting the modernization process of French agriculture since the 1960s, including intense mechanization, crop specialization and land concentration. In 2010, 90% of the French arable cropland belonged to farms larger than 50 ha, 25% to farms larger than 200 ha (Ministère de l'Agriculture et de l'Agroalimentaire-SSP, 2012).

The interviewed farmers were identified with the help of the "Departemental Chambre d'Agriculture", a professional structure representing the farmers and providing them technical advice. The objective was to constitute a sampling of the most common professional (arable crop) farms in the Toulouse metropolitan region. The sampling didn't respond to statistical representativeness, regarding the nearly 3,800 farms dedicated to arable cropping in the metropolitan region, according to the 2010 agricultural census. Its building responded more to the ambition to grasp and understand the diversity of strategies the arable farmers have adopted to maintain and develop their activity in a metropolitan context. To constitute the sample, three criteria are considered: the diversity of (i) locations in Toulouse FUA, (ii) farm size, and (iii) activities and production modes (including one organic farmer and one farmer using soil conservation practices). Among the surveyed farmers, five are situated in the inner city of Toulouse, the remaining 10 farms are in the peri-urban ring of the metropolitan region. These farmers had inherited farms from their parents or were still holding farms in association with them.

The interviews focused on the professional life histories of the respondents in order to investigate their relationship with the local context of their professional activity (Duvernoy and Paradis, 2016). During these interviews, information was collected on farm's characteristics, including land-use and land tenure, farmer's activities and farm changes since the farmer installation. Table 4.7 reports the location of each farm, indicating the distance from Toulouse, farm size, length of activity's period, kind of production, multiple economic activity and income.

Table 4.7. Characteristics of farmers interviewed.

Location of the farm headquarter	Distance (min. from Toulouse)	Farm size (ha)	Starting year	Diversity in productions, activities or income
Inner city	26′	< 100	1980 to 1990	Pluri-activity,
	26′	< 100	1990 to 2001	Vegetable, Direct marketing
	20′	> 399	< 1980	Agricultural contracting

	23′	100 to 199	1990 to 2001	Agricultural contracting
	23′	200 to 299	< 1980	Recreation
Commuting zone	27′	< 100	1980 to 1990	Livestock farming, Pluriactivity
	27′	200 to 299	< 1980	Agricultural contracting
	27′	200 to 299	1990 to 2001	-
	28′	300 to 399	1990 to 2001	-
	37′	< 100	1990 to 2001	Pluri-activity
	71′	< 100	1980 to 1990	Direct marketing
	30′	100 to 199	< 1980	Agricultural contracting
	33′	100 to 199	1980 to 1990	Livestock farming
	56′	100 to 199	1990 to 2001	Direct marketing
	33′	200 to 299	1990 to 2001	Recreation, direct marketing, agricultural contracting,

Farms trajectories reflect adaptations to socioeconomic and territorial changes (Busck et al., 2006). Such trajectories were reconstructed according to Inwood and Sharp's proposal (2012). Their model considers different adaptation strategies for farms situated at the rural-urban interface. The farms with no heir are hypothesized to attract limited investments, possibly declining over time due to disinvestment strategies. The remaining farmers may adopt two different development strategies, namely 'horizontal' and 'vertical' growth. The first one consists on a spatial extension of the farm towards a production increase. It is a common trend in France where the number of farms decreased by 52% between 1988 and 2010, while their agricultural land decreased only by 6% (Insee, 2013). In arable crops, this is a general feature to consolidate farmer's revenue, being more difficult in urban areas, due to the competition with other uses of land under high and rapidly increasing price regimes. Vertical growth allows maintaining (or increasing) revenues on an unchanged land base, by promoting new agricultural activities and complementary non-agricultural businesses on-farm.

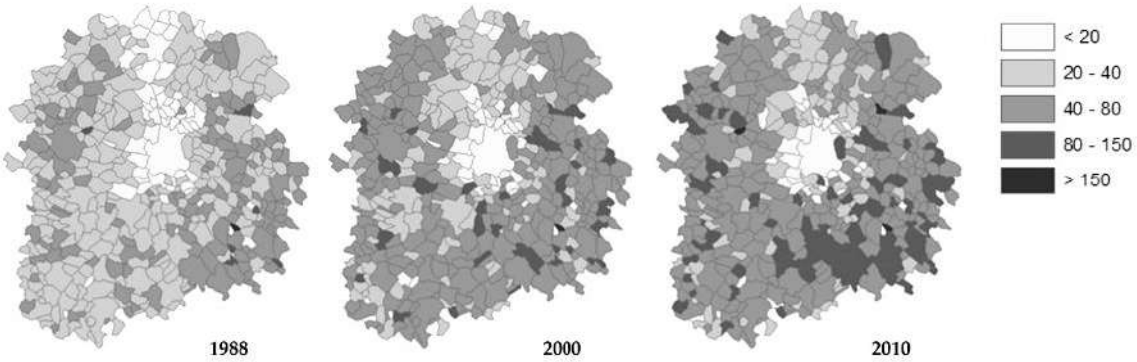
The information collected during the farmers' interviews allows reconstituting farm socioeconomic trajectories, considering (i) diversification in crop types, agricultural activities and sources of income, and (ii) changes over time in farmland composition and structure. The first-dimension concerns both activities carried out to diversify the farmer's incomes (farming activities for third-parties including agricultural contracting, or non-farming activities, namely pluri-activity) and other activities indirectly linked with the primary production of the farm (e.g. product transformation, direct marketing, recreation and accommodation). On the second dimension, farmers answered questions about their cultivated land, providing indications on the size of their farm, the constitution of their land holding along the generations and since their own installation, and on changes in the location of the parcels (both owned or rented for years) due to urbanization. For the farmers who agricultural contractors were, a similar question was made for the parcels that they were charged to cultivate by third-parties (e.g. landowners with the legal status of farmers but no cultivation activity). These data were used to describe the farms scales.

To identify economic trajectories of farms, the three pathways identified by Inwood and Sharp (2012) were considered: (i) disinvestment, (ii) horizontal growth, and (iii) vertical growth. A disinvestment process can be identified in the following factors: decline in farm size, willingness to sell the land, pluri-activity and farming intended as a secondary activity. Horizontal growth was evaluated as an increase in the size of farms since the farmers' installation. Vertical growth was defined as a diversification in production activities (transformation, direct selling) or farming activities (on-site accommodation and recreation). Interviews allowed us to identify a fourth

pathway, where another source of revenue is due to agricultural activities for other economic agents: (iv) diversification by agricultural contracting.

4.3.2. Mapping peri-urban agriculture and spatio-temporal trajectories in Toulouse

A generalized reduction in the number of farms and a moderate loss in total utilized agricultural area were observed between 1988 and 2010, determining an evident increase in farm size which was stronger in the south-eastern part of the metropolitan region (Figure 4.15a). In the first-time interval (1988-2000), the utilized agricultural area decreased mainly in urban municipalities around Toulouse. In the subsequent time interval (2000-2010), farmland loss was less concentrated on the inner city (Figure 4.15b). An improved description of peri-urban farming systems in Toulouse was derived from the analysis of the spatial distribution of selected variables referring to 2010 (Figure 4.15c). Toulouse and the surrounding urban municipalities include medium-small farms held mostly by individual farmers with intermediate (and sometimes high) education levels. Opposed to family and corporate farms, the number of individual farms increased especially around Toulouse during 2000-2010. Descriptive statistics and maps contribute to identify some interesting features of peri-urban agriculture in the Toulouse metropolitan region. Farm size increased with the distance from Toulouse. A general increase of farm's utilized area during the study period was observed in municipalities far away (> 20 km) from Toulouse; the reverse pattern was recorded in peri-urban municipalities distant < 20 km from the inner city. The percentage of individual farms increased moderately in the study area, with farm holders declaring high levels of education and no direct successors; most of them are relatively young (< 55 years old) compared with the regional/country averages. Farms specialized in intensive livestock, primarily managed by pluri-active farm-holders, were relatively scarce in fringe municipalities around Toulouse. By contrast, farms with highly educated farm-holders decreased with the distance from Toulouse.



(a)

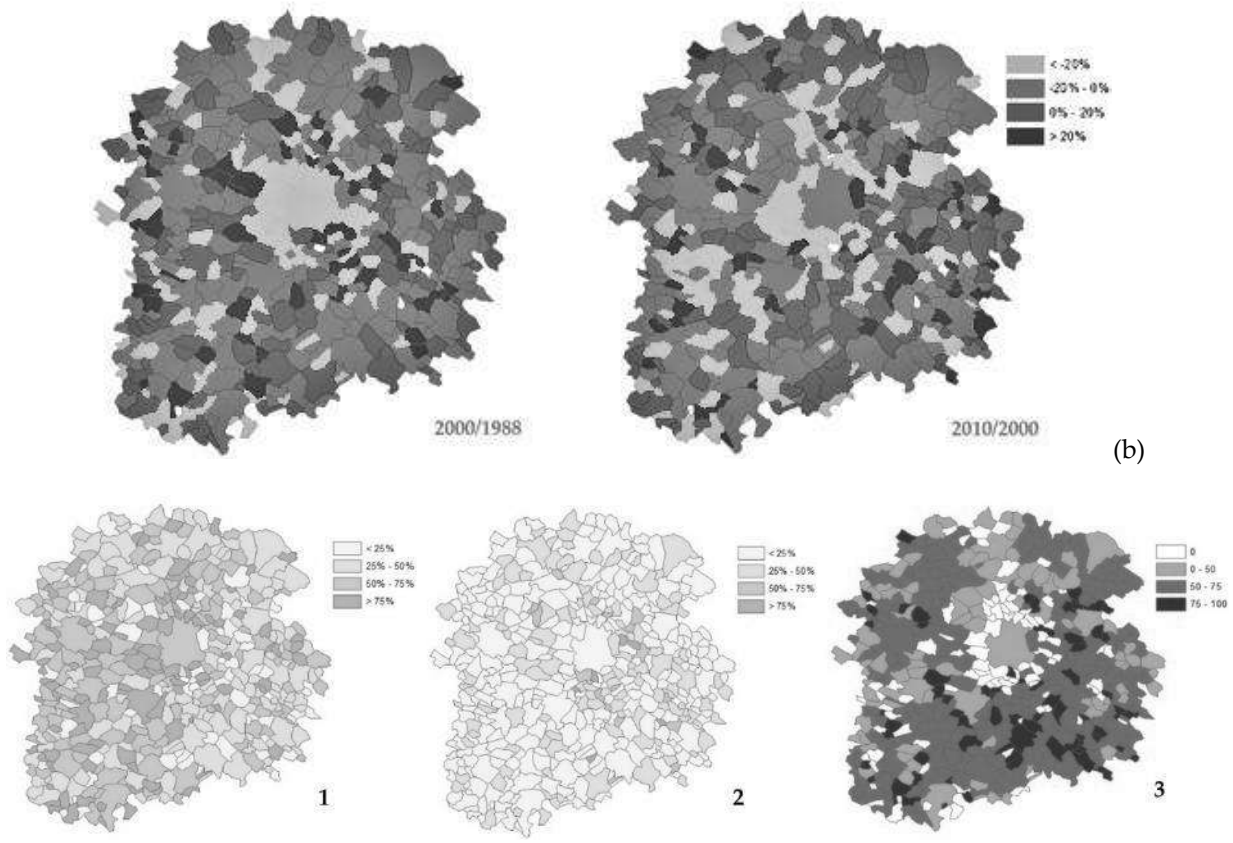


Figure 4.15. Average utilized agricultural area of farms (hectares) by municipality in Toulouse metropolitan region (a); Percent change over time in average agricultural utilized area in Toulouse metropolitan region (left: 1988-2000; right: 2000-2010) (b) ; Percent share of individual farm surface in total Utilized Agricultural Area (UAA), 2010 (1); percent share of farm-holders with high education in total farms, 2010 (2); percent share of agricultural area (UAA) of farms > 100 ha, 2010 (3) (c).

Results of a Principal Component Analysis (PCA) run on the indicators' matrix are reported in Table 4.8. Component 1 explained 19.5% of the total matrix variance and discriminates two farming systems in the study area respectively characterized by: (i) individual farms without successors, concentrated in the inner city of Toulouse (positive component scores, Figure 4.16) and (ii) large-size farms located in municipalities > 20 km away from Toulouse (negative component scores). The average farm UAA and the percentage of holdings without known successor (2010) received positive loadings. A negative correlation with component 1 was found for livestock farms in 1988 and 2000, medium- and large-size farms in 2010, farms with permanent employees in 2010, individual holdings in 2010 and changes in the UAA (2000-2010). Component 2 (9.3% of the total matrix variance) identifies a specific type of farms specialized in intensive livestock and concentrated in the southern part of the metropolitan area, especially in municipalities far away (> 30 km) from Toulouse. Based on component loadings, these farms are frequently directed by farm-holders with medium-high education level and having multiple jobs. Component 3 (7.5% of the total matrix variance) identified environmental and social factors associated with the economic dimension of farms. Negative loadings were observed for irrigated area (2010), change in total UAA (2000-2010), farms with a UAA > 100 ha (2010), average farm gross income and holdings without known successor (2010). Component 4 (6.2% of the total matrix variance) identified a social gradient,

distinguishing farms with elder and young holders. To a certain extent, processes of farmer ageing have characterized the most typical farm type in Toulouse's urban area since the late 1980s. Percentage of farmers < 40 years old in each studied municipality received negative loadings; conversely, average farm gross income (2010), share in the UAA (2010), percentage of livestock-specialized farms, and share of holdings without known successor in total farms received positive loadings. Municipal scores of components 3 and 4 showed higher spatial heterogeneity than scores of components 1 and 2 (Figure 4.16).

Table 4.8. Principal component loadings of agricultural indicators (bold indicates relevant loadings > |0.4|).

Variable	PC 1	PC 2	PC 3	PC 4
Farm-holders < 40 years in total farm-holders, 2010 (%)	-0.15	-0.10	-0.29	**-0.65**
Farm-holders < 40 years in total farm-holders change 2000-2010 (%)	0.12	-0.20	-0.30	**-0.46**
Farm rent: share in the UAA, 2010 (%)	-0.34	-0.24	-0.04	-0.20
Irrigated area in total farm area, 2010 (%)	0.08	-0.21	**-0.55**	-0.20
Seasonal workers, 2010 (%)	0.01	-0.15	-0.25	-0.19
Part of the drained area, 2010 (%)	-0.19	-0.02	-0.05	-0.13
Livestock farms, 1988	**-0.48**	**-0.50**	0.23	-0.07
Livestock farms, 2000	**-0.46**	0.16	0.13	-0.10
Livestock farms, 2010	-0.19	**0.70**	-0.34	-0.10
Heads of operations and pluri-active farm-holders: share in total farmers,2010 (%)	-0.17	**0.81**	-0.24	-0.10
Arable land in the UAA, 2010 (%)	0.04	-0.15	0.35	-0.09
Farm-holders with high education: share in total farms, 2010 (%)	-0.19	**0.68**	-0.15	-0.04
Share of medium-large farms UAA, 2010 (%)	-0.07	-0.37	-0.04	-0.04
Medium density and large farms, 2010 (%)	**-0.67**	-0.14	-0.13	-0.02
Farm-holders: variation, 2000-2010 (%)	0.34	**0.66**	-0.14	0.00
Permanent employees, 2010 (%)	-0.22	0.00	0.29	0.01
Total UAA evolution, 2010-2000 (%)	-0.17	-0.32	**-0.48**	0.06
Share of agricultural area (UAA) of > 100 ha farms in total farms, 2010 (%)	-0.34	-0.10	0.21	0.06
Farms with permanent employee: share in total farms, 2010 (%)	**-0.80**	0.09	-0.06	0.06
Farms with an agricultural area (UAA) of > 100 ha, 2010 (%)	-0.33	-0.21	**-0.50**	0.09
Individual holdings: share in the UAA, 2010 (%)	**-0.87**	0.10	-0.03	0.09
Farms UAA average, 2010 (ha)	**0.71**	0.12	0.10	0.09
Farm UAA average, 2000 (ha)	**-0.52**	0.03	0.43	0.13
Share of individual holdings in total farm UAA, variation (2000-2010)	**-0.80**	0.12	0.04	0.15
Farms UAA average, 1988 (ha)	0.19	0.06	-0.02	0.17
Average standard farm gross income: variation 2010-2000 (%)	**-0.72**	0.11	0.09	0.18
Average standard farm gross income, 2010	-0.02	-0.20	**-0.53**	**0.48**
Holdings without known experienced successor, share in the UAA, 2010 (%)	-0.17	-0.17	**-0.58**	**0.49**
Holdings without known experienced successor, share in total farms, 2010 (%)	**0.41**	-0.02	0.01	**0.52**

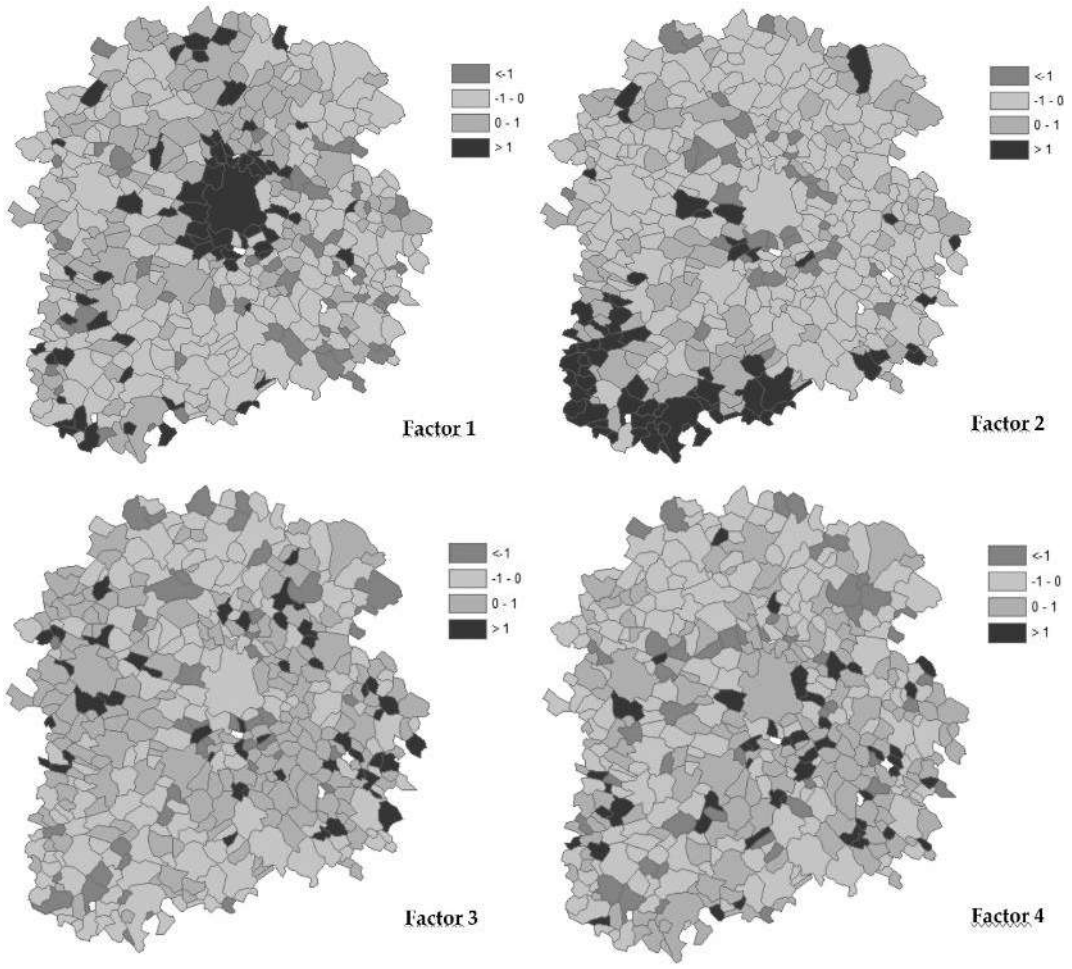


Figure 4.16. Municipal scores to selected principal components ('factors') in Toulouse metropolitan region.

Correlation analysis investigates the relationship between selected background variables (distance from Toulouse, average elevation, municipal surface, population size and density) and indicators assessing the main characteristics of farming systems in Toulouse (Table 4.9). Pearson correlation coefficients identified the most relevant indicators associated with the urban-rural gradient in Toulouse: (i) medium-large farms (r = 0.23), farms with UAA > 100 ha (0.20), average farm UAA (0.21) and the proportion of livestock-specialized farms in total farms (increasing from 0.42 in 1988 to 0.46 in 2010). Distance from Toulouse was counter-correlated with percentage of farm-holders with high education (-0.21), share of arable land in total UAA, 2010 (-0.28), and share of permanent employees in total farm workers, 2010 (-0.25). Average elevation was positively correlated with average farm UAA in 1988 (0.27), economic size of farms in 2010 (0.23), and proportion of livestock farms in total farms (with a correlation coefficient increasing from 0.43 in 1988 to 0.46 in 2010). Seasonal workers (-0.29) and the shares of irrigated land (-0.30), and arable land (-0.22) in total farm UAA decreased significantly with average elevation at the municipal scale.

Table 4.9. Significant Pearson correlation coefficients between agricultural indicators and background variables in Toulouse metropolitan area ($p < 0.05$ after Bonferroni's correction for multiple comparisons).

Variable	Distance from Toulouse	Average elevation	Population density
Farm-holders: variation, 2000-2010 (%)			-0.22
Farm-holders with high education: share in total farm-holders, 2010 (%)	-0.21		
Farms with an agricultural area (UAA) of 100 ha or more in 2010 (%)	0.20		-0.31
Share of agricultural area (UAA) of farms of 100 ha in 2010 (%)			-0.33
Individual holdings: share in the UAA, 2010 (%)			0.21
Holdings without known successor, share in total farms, 2010 (%)			0.21
Holdings without known successor, share in the UAA, 2010 (%)			0.29
Share of irrigated land in total cropland, 2010 (%)		-0.30	0.20
Share of medium and large farm UAA in total UAA, 2010 (%)			-0.21
Medium density and large farms, 2010 (%)	0.23		-0.33
Farms UAA average, 2010	0.21		-0.33
Farms UAA average, 2000			-0.33
Farms UAA average, 1998	0.21	0.27	-0.37
UAA change, 1982-2000 (%)	0.12	0.08	-0.28
Arable land in total UAA, 2010 (%)	-0.28	-0.22	-0.10
Share of permanent employees (%) in total employment, 2010	-0.25		
Seasonal workers, 2010 (%)		-0.29	
Livestock farms, 1988	0.42	0.43	
Livestock farms, 2000	0.50	0.51	-0.20
Livestock farms, 2010	0.46	0.46	

Population density was correlated positively with the shares of individual holdings (0.21) and holdings without known successor (0.21) in total farms and with the share of irrigated land in total UAA (0.20). Population density was inversely proportional to changes in the number of farm-holders between 2000 and 2010 (-0.22), farms with UAA > 100 ha (-0.31), share of agricultural area of farms with UAA > 100 ha (-0.33), share of medium-large farms in total UAA (-0.21), average farm UAA (-0.37 and -0.33 respectively in 1988 and 2010), changes in farm UAA between 1988 and 2000 (-0.28) and livestock farms in 2000 (-0.20). Municipal surface area and absolute population size did not show significant correlation with any farm indicator considered.

Multiple farm trajectories over time were reconstructed in the study area relying on the main characteristics of the farms derived from the survey described (Table 4.10). Economic disinvestment was identified in three farms (i) with stable or decreasing size, (ii) where farmers had other jobs as main activity, and (iii) with farmers willing to sell land for building. The remaining farms have experienced horizontal or vertical growth since the previous generation of farmers. For three farms, a classical process of horizontal growth was observed.

Table 4.10. Farm trajectories by farm size in Toulouse.

Farm trajectory	Farm area (land-owned or rented, ha)				
	< 100	100 to 199	200 to 299	300 to 399	> 399
Maintenance/disinvestment	3				
Horizontal growth		1	1	1	
Horizontal growth + agricultural contracting		2	1		1
Horizontal and vertical growth				1	
Vertical growth	2	1			

For three farms, vertical growth strategies were identified. One of these farmers explained that he has been willing but unable to expand his cropland due to chronical land shortage in fringe districts. This farmer then decided to develop a more intensive production of vegetable crop on a few hectares, progressively offered to Community Supported Agriculture (CSA) groups or sold in local markets. Another farmer has declared that her development project on her father's farm was directed to field crop transformation (flowers, pastas, oil, bread) and direct selling. She aimed at adding value to local productions without increasing farm size. However, horizontal and vertical growth were sometimes identified as joint mechanisms of farm development. Two farmers have increased the size of their farms while developing recreational activities or improving mechanisms of transformation and direct selling of crop productions; one of them resulted to be also a farm contractor.

Finally, five farmers directed an activity based on agricultural contracting. One of these contracting firms was founded by the grand-father of its actual holder. These contracting firms are well equipped and contracted by other farmers to execute one step of the production process or to carry out the entire production process. It was estimated that the activities of these five firms were responsible for the production of more than 1000 ha, working for landowners who maintain the status of farmers while being only indirectly involved in farming. One of these five agricultural contractor has developed recreational activities and direct selling of local products in his own farm, as mentioned before.

Considering a larger time scale, the interviewed farmers have reported a story of horizontal growth and crop specialization over generations. The increase in farm size since their grand-fathers' or fathers' times has been possible with the purchase and land renting of abandoned farmland. This horizontal growth strategy influenced the production scale of the farms in the study area, which can extend far beyond the municipal limits. Particularly, the farmers holding agricultural contracting activities have declared to contract sometimes at more than 20 km from their headquarters (Figure 4.17).

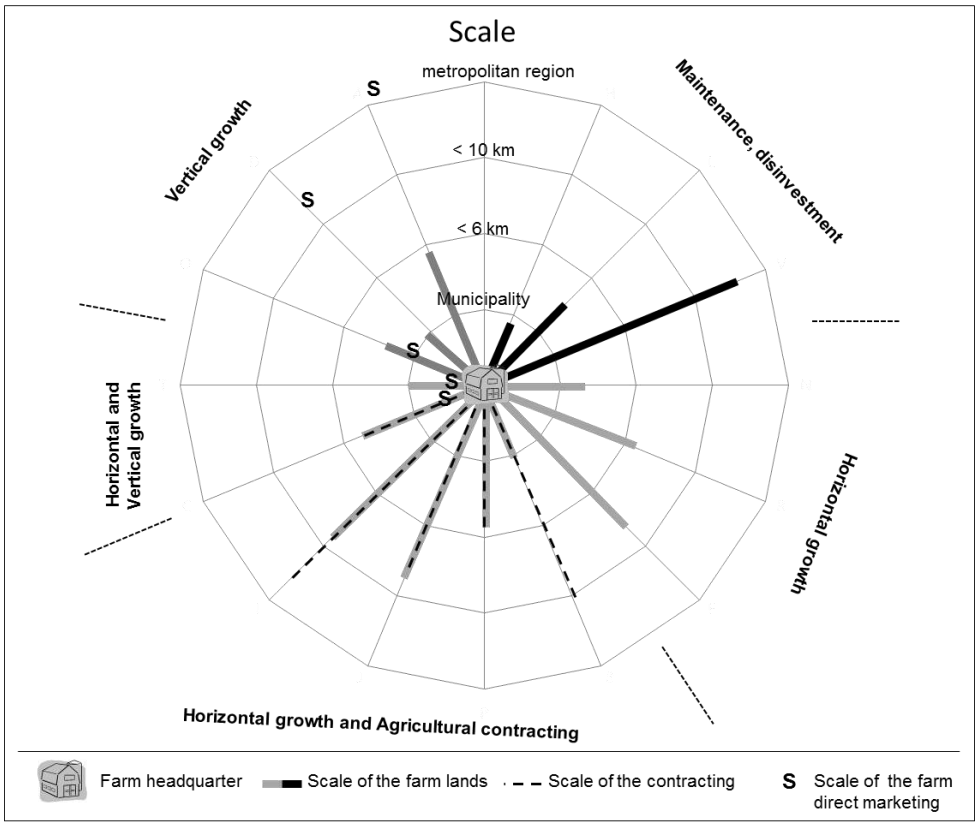


Figure 4.17. Farm scales in the Toulouse metropolitan region based on farm trajectories identified by interviewing a sample of 15 peri-urban farmers (each vertex represents one of the farms).

Inwood and Sharp's model of farm adaptation to urban areas allowed identifying elementary strategies to cope with urbanization. Farm changes resulted from the adoption of one or several of these basic strategies. For two of the farmers interviewed horizontal and vertical growth were non-exclusive. For some farmers vertical growth, i.e. diversification in terms of production and activities in farms, was the only strategy they could develop due to the difficulties to expand their land area. Nevertheless, data show that vertical growth has not been reserved to small farms: some farmers with farms bigger than 100 ha have also diversified their activities. Managing an agricultural contracting firm seems to represent an intermediate strategy for some farmers, assuring a second income derived from crop production activities in other farms.

4.3.3. Pictures from the other side of the fringe

Sustainable development of peri-urban areas represents a challenge for European cities (Antrop, 2005). Agriculture in peri-urban areas may assume a strategic importance in the stability and quality of the urban environment (Perrin et al., 2013; Salvati and Carlucci, 2014). Peri-urban farming could play a characteristic multifunctional role oriented to biodiversity preservation, sustainable management of natural resources, conservation of local culture and traditions, food security, wellness and healthiness (Hall et al., 2004; Cimini et al., 2013; Marchetti et al., 2014). With this perspective in mind, the document entitled "Objective Lands: 2020. For a new French agricultural model", edited by the French Ministry of Agriculture in 2008, underlined the need of a new sustainable agricultural model. Understanding site-specific characteristics of urban and peri-urban farming systems is a key to design territorial strategies targeting future needs for both urban and rural areas (Vandermeulen, 2006). However, this linkage is hindered by an incomplete institutional

vision and the scarce attitude of local actors to identify (and understand the importance of) specific territorial and ecological requirements of local cropping systems (Simon Rojo et al., 2014).

By considering together quantitative and qualitative analysis of farms and farmers in Toulouse metropolitan region, the empirical results seem to reflect both the effect of urbanization on farms and the ability among farmers to cope with multiple adaptations to urban/peri-urban environments characterized by inherent conflicts in the use of land, land consumption, farmer entrepreneurialism and the concentration of holdings among non-farmers. The analysis integrates long-term, general trends in farming systems at the regional scale with place-specific dynamics more likely driven by the characteristic local context, strongly influenced by the dispersed expansion of Toulouse's urban fabric. Within this framework, divergent evidences arise from the qualitative analysis. Farmers interviewed produce common crop types, considered to be commodities, on large farms. The farmers who could not enlarge their farms pursued relevant opportunities to increase farm income through value-added production or associations with alternative agricultural governance models. Both strategies are in line with Inwood and Sharp's (2012) models of farms trajectories, through horizontal and vertical growth. Hybrid trajectories, where both strategies are pursued by the same farmer, were also observed in the study area. In this direction, the magnitude of agricultural contracting in the survey offers another view of horizontal growth, but also of farms persistence in Toulouse metropolitan area: part of the surveyed farmers is land-owners who contract such enterprises (Duvernoy and Paradis, 2016). Part of the urban and peri-urban agricultural landscape is cultivated by such contractors. With the estimation of the farmer activity scales, the study in Duvernoy et al. (2018) shows that farmers' strategies, including farm enlargement, short supply chains or agricultural contracting, can extend far beyond municipal limits. At the same time, it identifies relevant attributes of peri-urban farming systems in the Toulouse's metropolitan area. The Toulouse's urban gradient - being reflected in a continuous decline of population density for municipalities progressively far away from the inner city - has emerged as a key variable shaping farm size, productive orientation of the farm systems, and farmers' socio-demographic traits such as age and education level. Livestock farming concentrated in peripheral districts with low population density and distance > 30 km from Toulouse.

This diversity of farms, farmers and productions could become an asset for the building of a metropolitan food system (Opitz et al., 2016).A range of cities has tried to develop local or regional food strategies which promote the inclusion of peri-urban farms in developing urban-based short supply chains, social justice and enhanced ecosystem services (e.g. Cavallo and Marino, 2012; Perrin et al., 2013; Serra et al., 2017). In the Toulouse context, this strategy implies that peri-urban farming must be included more effectively in a regional agricultural system governed by regional and local authorities (de Groot, 2006), better informed on the actual trends of metropolitan farming systems. Quantitative results confirm the well-known conflict between urban development and agriculture, evidencing also a high level of diversity in crop productions at the metropolitan spatial scale. Qualitative data focusing on the predominant production of arable crops highlight the increasing scale at which farmers develop their strategies of change, to expand their farm or their contracting activity as agricultural contractors. The few cases of diversification towards other productions, short food chain and recreational activity are signals of possible linkages between the considered conventional farming and the urban food system.

To overcome spatial planning problems, policy decisions should focus more specifically on suburban issues regarding sustainable management of peri-urban spaces (Bonnin-Oliveira, 2012; Barbati et al., 2013; Perrin, 2013), in Toulouse as in other Mediterranean cities and metropolitan regions (e.g. Abrantes et al., 2010; Biasi et al., 2015; Soulard et al., 2017).

The need to conceive peri-urban agricultural areas in a larger, regional green network, has underlined the importance to solve questions linked to the lack of information related to the socioeconomic features of peri-urban agricultural systems. Territorial strategies suitable to link characteristics of such systems to specific processes of urban development have become particularly urgent in contemporary metropolitan regions. By integrating qualitative with quantitative approaches, the study in Duvernoy et al. (2018) provides a thorough reading of the evolution of an urban model from the point of view of peri-urban spaces. It outlines the importance of understanding together urban development dynamics and peri-urban farming evolution with the aim to envisage future strategies of sustainable land management. In this sense, future research should clarify key issues such as the changing structure of peri-urban farming, the emergence of multi-stakeholder agriculture operating on fringe land, the inherent impact of the recent reforms of European Union agricultural subsidies on peri-urban farms. A specific effort should be deserved to assess the intimate relationship between regional planning and peri-urban farming, investigating e.g. municipal spatial governance, food provisioning and non-food agricultural land uses within socioeconomic contexts characterized by different urban-rural functional synergies.

4.4. Urban sprawl and the 'olive' landscape

For a long time, agriculture in both affluent and emerging countries has been likely the land-use most affected by urban expansion (Foley et al. 2005, 2011; Amato et al. 2016). At the same time, the contribution of agricultural areas - especially tree crop - to resilient cities and sustainable peri-urban landscapes has been increasingly debated (Colantoni et al. 2015; De Zeeuw et al. 2011; Olsson et al. 2016; Palazzo and Aristone 2017). Peri-urban cropland has been first regarded as a land stock waiting for urbanization (Aubry et al. 2012; Serra et al. 2014; Pili et al. 2017). The increasing role of cropland in urban sustainability and resilience reflects the growing need for food recently manifested by cities (Schewenius et al. 2014). The spreading demand of fresh food by urban population emerged together with the multiple socio-environmental functions provided by rural areas to metropolitan systems, including new job opportunities, improvement of local economic systems and prevention of environmental risks, e.g. soil degradation, land consumption, wildfires and overgrazing (Bhatta 2010; Friel et al. 2007; Cimini et al. 2013).

In this regard, the use of tree crops - and especially olive trees - as a bio-climatic and landscape indicator has been progressively consolidated in environmental studies (Moriondo et al. 2013). Although the spatial distribution of the olive tree in Europe is associated to a relatively well-defined latitudinal gradient, empirical evidence demonstrating a recent shift towards northern regions in the geographical range of this crop has been increasingly collected (Moriondo et al. 2008; Audsley et al. 2006; Gutierrez et al. 2009; Olesen et al. 2011; Tanasijevic et al. 2014). These results are particularly interesting since they suggest how land mismanagement and climate variations - at both regional and local scale, from single cities to larger metropolitan regions - may drive changes in the use of land impacting vegetation cover and soil quality (Marathianou et al. 2000), transforming (e.g. simplifying or fragmenting) traditional landscapes (Moriondo et al. 2006).

Cited article

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Tree crops are probably the most widespread cultivation around cities, especially in long-inhabited peri-urban environments surrounding metropolitan areas in Europe (Salvati et al. 2015). Together with vineyards, olive tree is a constitutive element of one of the most diffused cropping systems in southern Europe (Aretano et al. 2013), representing a typical crop along mixed urban-rural settlements. Olive groves in Mediterranean landscapes provide key environmental services, assuring biodiversity preservation and aesthetic quality of peri-urban landscapes, and indirectly supporting rural economies and tourism development (Cohen et al. 2015; Cuadrado-Ciuraneta et al. 2017; Ferrara et al. 2014; Loumou and Giourga 2003).

The olive tree is likely the most traditional crop in Mediterranean landscapes, which has been often defined as the "olive tree geographical area" (Salvati et al. 2015). The geographical range of olive tree was frequently used to define the boundaries of the Mediterranean region (Braudel 1985). Olive trees have been traditionally cultivated since the antiquity and olive groves have been a widespread land-use across the Mediterranean basin for centuries (Makhzoumi 1997). Its long cultivation history and economic exchange has determined a remarkably high crop variability reflected in different agronomic and cultural traits of the landscape. Rapid socioeconomic

transformations in dynamic metropolitan regions have frequently threatened this cultural and natural heritage (Ferrara et al. 2015).

If Romans have had a key role in spreading cultivation of olive grove (Moriondo et al. 2008), traces of this 'holy' plant in Greece are grounded in the mythology: the goddess Athena was planting the first olive tree in the Acropolis of Athens after the father Zeus has asked her to create something useful for humanity (Loumou and Giourga 2003). According to Salvati et al. (2015), mythology indicated Greece as the original country of olive tree, a sacred plant traditionally protected from damaging or cutting. The sacral perception of olive tree is common in the three monotheistic religions spreading in the Mediterranean area during centuries and founding symbolical references to olive tree as the plant of regeneration, reconciliation, life and source of light.

Especially in small islands and interior rural areas, local communities devoted to agriculture still depend on olive production (Loumou and Giourga 2006). The introduction of mechanization into highly demand-driven cultivation operations, such as harvesting, has been key to economic sustainability of olive crop (Vieri 2002). More recently, olive oil production become one of the most relevant items of short chain systems worldwide. According to Orsini (2013), success of short economic chains depends from external factors and an enhanced awareness of the importance of local cropping practices, rural traditions and food products. First, the olive's fat is recognized as a "healthy" local production, reversing the constraints typical of the relationship between human subjects and fetishized commodities, and feeding the dichotomy between local culture and the economy (Meneley 2004).

Second, olive production short chains have a great potential to drive toward an informal economy (Kizos et al. 2011). Small bottlers are the one who receive the most benefits in the Greek context, as they can ignore big retailers (Kizos and Vakoufaris 2011). While complex and competitive international markets create uneven impacts on olive crop (Moissidis and Duquenne 1997), the combination of tourism and city food assets may improve the economic success of short chains based on products of rural landscapes dominated by olive crop because of food trustworthiness, (ii) the emerging socio-cultural traditions and (iii) the increasing linkage between urban areas and local food production (Paul and Mckenzie 2013).

As the food system of any given area has a great importance in determining its cultural frame, olive oil is the base of the Mediterranean diet - providing the main source of fat -, becoming a recognized symbol of this diet at the same time (Makhzoumi 1997). In this regard, Pecqueur (2003) has evidenced a great (economic and environmental) value in what can be developed around a traditional agricultural product such as olive. Buying a product leads to an economic return and an added value of this product at the territorial level. This additional value is attractive for both residents and tourists (Giourga and Loumou 2006). The informal, small-scale production models typical of Mediterranean rural areas can be maintained and, possibly, enhanced through these short chains (Kizos 2010). For example, Mediterranean uplands have been long characterized and managed by rural populations through terraces, whose landscapes are frequently dominated by olive groves (Savo et al. 2014; Tsilimigkas and Kizos 2014; Biasi et al. 2015; Karamesouti et al. 2015). At the same time, relict woodlands with wild olive trees are considered crucial elements of peri-urban landscapes associated to high biodiversity, aesthetic beauty and key ecosystem services, including protection from soil erosion (Cutini et al. 2015; Haberl et al. 2004; Serra et al. 2008). Farmers

in peri-urban landscapes dominated by olive groves were demonstrated to adopt specific agricultural practices for land resources management, more frequently than their counterparts operating in intensive cropping systems (Agnoletti et al. 2011; Brunori et al. 2016; Sabbi and Salvati 2015; Tombolini et al. 2014). However, research is increasingly required to identify factors affecting a sustainable use of land, improving agricultural productivity, social cohesion and ecological sustainability at the same time (Serra et al. 2008; Salvati and Carlucci 2011; Kelly et al. 2015; Kosmas et al. 2016).

Analyzing the socioeconomic context underlying persistent olive agro-systems in metropolitan Greece, contributes to understanding the role of food production in evolving peri-urban landscapes, considering that farmers are key actors in sustainable land management (Kristensen et al. 2001). In man-made environments typical of the Mediterranean region, a sustainable land management strategy for metropolitan regions is increasingly required to quantify long-term and short-term land-use changes, identifying trends in their driving factors (Antrop 2000, 2004; Colantoni et al. 2015; Tanrivermis 2003; Briassoulis 2008).

Informal settlements have reflected spontaneous urbanization in the Mediterranean basin, determining uneven land consumption (Leontidou 1990; Kourliouros 1997; Grekousis et al. 2013; Colantoni et al. 2016). Uncontrolled urbanization has negatively impacted natural environments (Chorianopoulos et al. 2010; Salvati et al. 2013; Zitti et al. 2015), transforming agricultural land into man-made spaces vulnerable to wildfires and land degradation (Moreira et al. 2011; Salvati et al. 2014, 2015). Negative effects of urbanization on environmental quality have been documented in several Mediterranean areas (e.g. Alphan 2003). For instance, 17% of land with olives in the fertile region of Izmir (Turkey) was converted to urban use, determining an accelerated rate of land consumption, soil degradation and deterioration of water resources (Kuruku and Kuçukyilmaz 2008). A study by Doygun (2009) about the loss of cropland in Kahramanmaraş, in the north-east area of the Turkish Mediterranean district, revealed that olive groves have decreased from 461 to 344 hectares for 20 years (1985- 2006) and were subjected to land fragmentation. About 60% of the olive grove surface lost in the study period was covered by urban settlements, resulting in a 10-fold increasing population. Because of intense landscape fragmentation, olive groves' loss will probably increase in the coming future with a consequent decrease of farmers' income, a rising rate of soil degradation, and the progressive reduction of cropping systems' complexity (Marull et al. 2008). Peri-urban landscapes resulting from a persistent loss of high-quality agricultural areas, such as olive groves, require a specific protection status (Economidou 1993).

As a result of multifaceted social processes, land-use changes involve several interacting actors (Garcia Latorre et al. 2001). Since the early 1980s, Mediterranean cities have experienced a rapid transition from mostly compact and dense models to various steps of a more discontinuous morphology characterized by huge expansion around the inner city (Schneider and Woodcock 2008). Trends toward ‘compact growth’ observed up to the early 1990s and the following ‘discontinuous urbanization’ have affected land-use structure and peri-urban farming in a different way (Salvati and Ferrara 2013), reflecting a spatially-varying rate of land consumption and high impact on specific crops (Salvati et al. 2015). How the changing use of land represents a target for policies mitigating soil consumption and promoting peri-urban agriculture in Mediterranean fringes has been discussed extensively (e.g. Salvati et al. 2014). In the first urbanization phase, observed in the first decades after World War II, urban expansion primarily involved poor-quality fringe land, such

as shrubland, pastures, abandoned agricultural fields, bare land and areas with poor spontaneous vegetation (Genske 2003; Johnson and Lewis 2007; Portnov and Safriel 2004). In the most recent expansion phase, rural land - often with high-quality soils - experienced more subtle changes in the use of land, mainly conversion toward discontinuous urban settlements (Salvati et al. 2013; Cakir et al. 2008; Gospodini 2009; Kosmas et al. 2016).

The work in Cecchini et al. (2018) focused on the Athens' metropolitan region, investigating long-term trends in peri-urban landscapes dominated by olive crops. Athens is considered a paradigmatic Mediterranean city (Leontidou 1990; Maloutas 2004; Arapoglou and Sayas 2009; Di Feliciantonio and Salvati 2015), with long-term development processes being representative of both 'compact' and 'dispersed' waves of urban expansion (Gospodini 2006; Chorianopoulos et al. 2010, 2014; Souliotis 2013; Carlucci et al. 2017; Rontos et al. 2016). The study hypothesized that olive groves - having a recognized cultural, culinary and aesthetic importance - may represent a relevant component of resilient fringe landscapes, representing an indirect green infrastructure to contain urban expansion (Zitti et al. 2015). Based on this assumption, the study is aimed to identify processes of urban growth and changes in peri-urban landscapes dominated by olive groves, offering new insights in sustainable land management strategies adapted to evolving metropolitan contexts.

4.4.1. Detecting olive groves

The Athens' metropolitan area experienced a millenary urban history coinciding, in the last two centuries, with the uneven expansion of Athens from less than 30,000 inhabitants in 1830 to more than 3.5 million inhabitants in 2010 (Leontidou 1990; Kallis 2010; Gargiulo Morelli et al. 2014; Salvati 2016). Since the late 2000s, the study area was experiencing a long period of economic recession (Kaika 2012; Souliotis 2013). The 2007 crisis, combined with austerity urbanism and neoliberal policy reforms, resulted in unprecedented unemployment and job insecurity, severe income decline, poverty and social unrest (Salvati et al. 2015; De Rosa and Salvati 2016). In a previous study on farmers' multiple activities in peri-urban districts of Attica (Moissidis and Duquenne 1997), nearly 40% of the household members who are in working age have declared to have two or more jobs, because peri-urban districts surrounding central cities offers more opportunities for alternative jobs than strictly rural areas.

Statistical indicators referring to the whole of the study area were constructed from census data by calculating the surface share of selected agricultural land-use types (annual crop, tree crops dominated by olive tree and grape) in total farm surface area for 6 points in time between 1961 and 2009. Additional indicators assessing agricultural and population dynamics (population density, share of rural population in total resident population, share of cultivated land in total land, per-capita cultivated land, share of irrigated land in total cultivated land) were computed along 4 recent decades between 1960 and 2000 using comparable statistical data derived from the national population register of Greece (population density) and the annual agricultural survey (the remaining indicators) carried out by ELSTAT. These indicators specifically refer to two distinct geographical partitions of the study area (the Greater Athens area and the rest of Attica).

The surface area of olive groves, fallow land and total cultivated land was assessed over 8 selected time points (1970, 1977, 1985, 1993, 2001, 2006, 2011, 2014) along the last five decades, calculating the total surface share of olive groves and fallow land in total cultivated land. Data were derived from the annual survey of agriculture held by ELSTAT and refer to the whole of the study

area. Changes in the total surface of olive groves in the last century (1911-2011) were assessed at a spatially-disaggregated spatial scale (municipalities) using official statistical data derived from the national annual survey of agriculture. The olive tree surface was calculated separately as a share in total municipal surface and in total regional surface (Attica) with the aim to assess (i) the geographical distribution of olive tree in the study area and to evaluate (ii) concentration of olive tree in specific districts, possibly outlining landscapes dominated by this crop.

A high-resolution map (1: 10,000) of the study area identifying urban, agricultural and forest land-use was finally used to illustrate the main landscape characteristics (the 2012 Urban Atlas map released by European Environment Agency under Copernicus Global Monitoring and Environmental Surveillance - Land initiative). Additional information collected from a field survey were used to select four case studies at the local scale (Athens, Acharnes, Maroussi and Irini) being representative of peri-urban landscapes with different land-use interactions and long-term conflicts between built-up areas, cropping systems and natural environments. The field survey, held by two authors (Luca Salvati and Anastasios Mavrakis) during 2012-2016, was based on a photographic survey of 186 sampling points along the Athens' urban fringe (nearly 150 km^2) located at the boundaries between the compact settlements of Greater Athens and the surrounding rural areas. Photographic materials, diachronic Google Earth maps, historical cartography and field interviews for each case allowed us to define long-term and recent land-use dynamics, focusing on the interaction between urban sprawl and olive groves. Four interviews were conducted to farmers (or past farmers) in each study site with open questions dealing with the recent evolution of landscape, land abandonment, agronomic practices and the issue of economic marginality of farms. The collected information was summarized in the results and forms a knowledge base for discussion.

A first case study allows investigating olive landscape dynamics over a long-time period encompassing the last three centuries, by a specific analysis of historical paintings and maps collected on the web or acquired using high-resolution photographs in local public libraries. These materials provide reliable data on the progressive olive disappearance in one of the most famous places close to central Athens (including the central district called 'Eleonas', in Greek 'Olive groves') mainly due to land abandonment, industrial development and compact urban expansion (Economidou 1993; Kourliouros 1997; Burgel 2004; Salvati et al. 2013). More recent 'olive landscape' dynamics in three districts located at the fringe of the Greater Athens area (Acharnes, Maroussi and Irini) were investigated using a photographic survey derived from Google Earth software at two points in time (2004-2005 and 2016-2017) and additional information collected by field survey. The selected aerial scenes illustrate persistence (or slow decline) of olive groves in rural areas under rapid urbanization and focus on olive parcels close to medium-low residential settlements, the most relevant expression of recent urban expansion in Athens (Beriatos and Gospodini 2004; Gospodini 2009; Chorianopoulos et al. 2014; Salvati 2016).

4.4.2. Investigating olive landscape dynamics

Athens has experienced one of the most rapid expansion of resident population, income and settlements in southern Europe (Leontidou 1990; Kallis 2010; Gargiulo Morelli et al. 2014). The Athens' metropolitan region was traditionally organized in a mono-centric structure (Zambon et al. 2017). The Athens' urban fabric is concentrated around the capital city, while rural areas extend the remaining part of Attica (Kourliouros 1997; Moissidis and Duquenne 1997; Colantoni et al. 2017).

The empirical analysis carried out here has distinguished the most urbanized contexts close to the Greater Athens area from the rest of the metropolitan region (Table 4.11). Long-term urban trends were explained along a 40-years' time period between 1960 and 2000 using selected population and agricultural variables. The Athens' urban area has lost its mono-centric characteristics over this time period, shifting to a discontinuous settlements' model expanding into lowland, rural Attica. A trend toward discontinuous urban expansion was observed since the 1980s in Athens (Giannakourou 2006; Delladetsima 2006; Couch et al. 2007), with prevalence of medium-low density settlements expanding along the sea coast and in Messoghia, eastern Attica, following suburbanization processes (Arapoglou and Sayas 2009; Chorianopoulos et al. 2010; Salvati et al. 2013). While population density has increased particularly in the metropolitan area, rural population has noticeably reduced: in the Greater Athens area, most of the resident population was classified as 'urban' since the 1970s, while an evident loss in 'rural' population (from 25% to 4%) has been recorded in the metropolitan region at large (Salvati 2016).

Table 4.11. Trends (1960-2000) in selected population and agricultural variables in the greater Athens area and in the remaining part of the Attica region (Greece).

Year	Greater Athens area					Rest of Attica				
	Population density (inhabitants/km²)	Rural population (%)	Cultivated land (%)	Irrigated/cultivated land (%)	per-capita cultivated land (ha)	Population density (inhabitants/km²)	Rural population (%)	Cultivated land (%)	Irrigated/cultivated land (%)	per-capita cultivated land (ha)
1960	4339	0.1	-	-	-	61	25.5	-	-	-
1970	5575	0.0	3.9	44.8	0.07	75	19.8	32.9	8.8	0.31
1980	6301	0.0	3.8	39.9	0.06	102	17.0	30.8	9.7	0.31
1990	6781	0.0	2.5	29.0	0.04	127	11.6	29.9	12.8	0.24
2000	7295	0.0	1.7	24.9	0.02	163	3.8	29.5	13.1	0.18

Coherently, the ratio of cultivated land in total land and per-capita cultivated land showed an evident decline over time. The ratio of irrigated land to cultivated land showed a considerable increase in the metropolitan area (from 8.8% to 13.1%), compared with the slight decline observed in the Athens' urban area (from 3.9% to 1.7%). Figure 4.18 shows the areas devoted to tree crops, and especially olive groves, concentrated along the Athens' urban fringe.

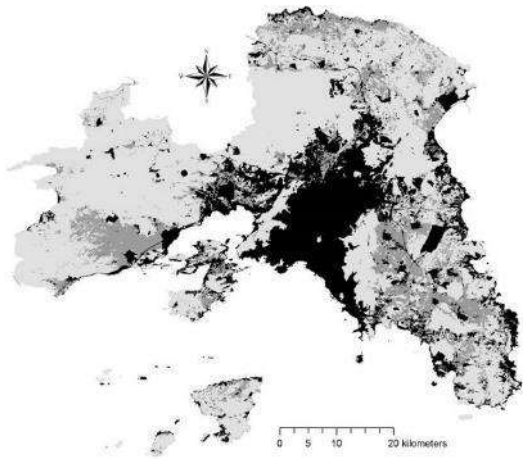


Figure 4.18. (left) Spatial distribution of basic land-use classes in the study area, 2013 (black: urban area, including roads; dark grey: tree crops including olive groves; light grey: other rural areas); (right); olive trees in Athens' fringe, 2016. Source: elaboration on Urban Atlas cartography and local information sources; authors' photographic collection.

Considering an enough long-time span between 1961 and 2009, the proportion of different agricultural land-use classes in total farmland is reported in Table 4.12 for the whole of Athens' metropolitan region. A consistent loss of annual crops was observed; grape wine surfaces were largely variable over time, while following a relatively more stable trend compared with annual crops. The only cropping system that has showed a continuous increase over time is dominated by tree crops, mainly olive trees. This context was associated with a rapid increase in the share of farmers active in the urban area in total farmers from 16% in 2000 to 29% in 2009. Overall, these results were reflected in a progressive concentration of agricultural surface owned by farmers living in the Athens' urban area from 2% to 6% in the same time period.

Table 4.12. Land-use, percentage in total farm surface area in the Athens' metropolitan region, by year.

Crop type	1961	1971	1981	1991	2001	2009
Annual crop	38.1	41.9	34.6	30.2	30.6	25.3
Tree crop (mainly olive)	20.2	31.7	43.4	40.8	46.2	52.2
Grape wine	16.3	19.4	16.0	18.8	14.2	13.0

Changes over time in the surface area of total cropland, olive groves and fallow land are reported in Table 4.13. A moderate (but continuous) loss of cropland was observed in the study area; fallow land increased up to the early 2000s and then decreased during the last decade. Olive surface increased continuously in both the greater Athens area and in the rest of Attica, growing from 19% to 46% in Attica between 1970 and 2014. These results demonstrate the persistency of cropping systems dominated by olive tree and forming a typical 'olive landscape' in peri-urban areas, although in a general context of rapid cropland loss due to compact urbanization (Chorianopoulos et al. 2010).

A specific analysis based on statistical data available at the municipal scale demonstrates that tree crop dominated by olive trees increased over time, becoming the most relevant land use in Attica's peri-urban farms. Figure 4.19 illustrates the spatial distribution of three indicators referring to 1911 and 2011: percentage of olive groves (i) in total municipal surface (%); (ii) in total regional surface (%); and (iii) percent change over time of both indicators.

Table 4.13. Surface area (ha) of cropland, olive groves and fallow land in Attica, 1970-2014.

Year	Total cropland	Olive groves	Olive groves (%)	Fallow land	Fallow land (%)
			Attica		
1970	1122	213	19.0	371	33.1
1977	1056	227	21.5	348	33.0
1985	1020	230	22.5	337	33.0
1993	979	246	25.1	333	34.0
2001	975	280	28.7	351	36.0
2006	770	236	30.7	264	34.4
2011	669	255	38.1	184	27.6
2014	531	246	46.3	104	19.6
			Greater Athens area		
1970	18.1	1.6	8.6	4.5	24.8
1977	15.6	1.6	10.1	3.9	25.1
1985	14.1	1.6	11.0	5.5	38.9
1993	10.1	0.9	9.4	5.3	52.6
2011	2.5	0.3	13.8	1.4	55.7
2014	0.3	0.1	49.3	0.0	10.7
			Rest of Attica		
1970	1104	211	19.1	367	33.2
1977	1040	226	21.7	344	33.1
1985	1006	228	22.7	332	33.0
1993	969	245	25.3	327	33.8
2011	667	255	38.2	183	27.5
2014	531	246	46.3	104	19.6

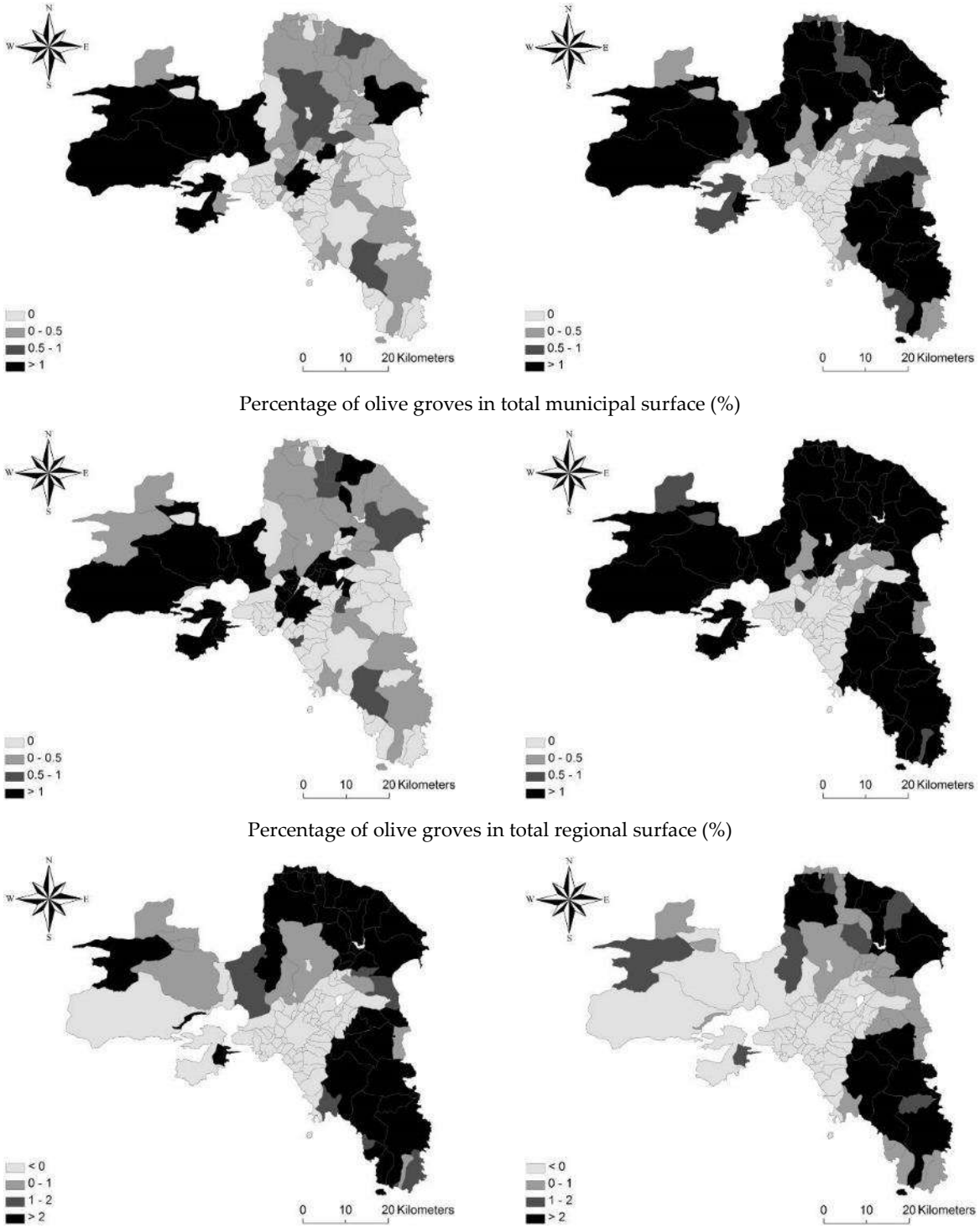
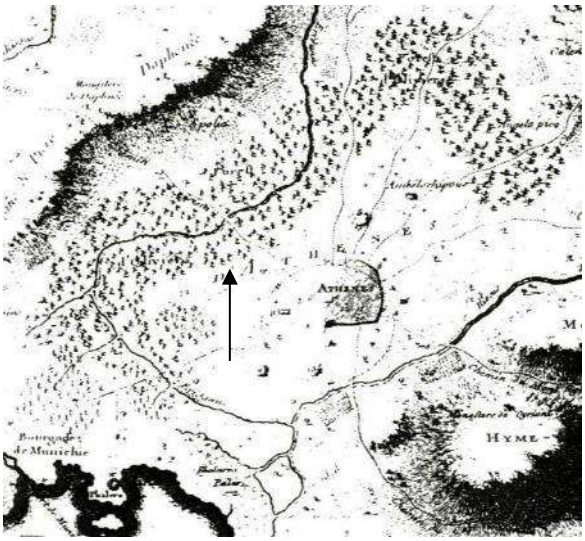


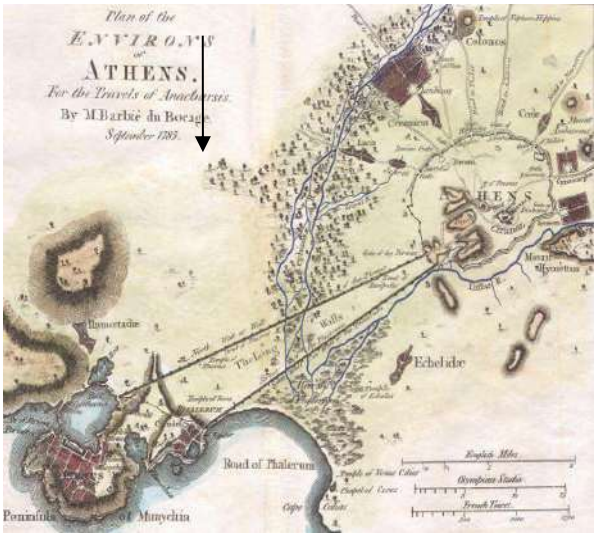
Figure 4.19. Spatial distribution of olive groves in 1911 (left) and 2011 (right). Source: own elaboration on ELSTAT data.

Olive tree surface expanded over time in rural and peri-urban areas, declining only in some urban districts surrounding Athens' inner city. In 1911, olive cultivations were concentrated in the western part of the region; in 2011, this crop was concentrated in eastern and northern Attica's districts; in a general context of rapid urbanization, the traditional area of Megara, was the only rural

district specialized in olive trees that was preserved from massive urbanization in western Attica. Maps revealed that north-eastern districts have witnessed the more evident spread of olive crops in the last century. Interestingly, olive groves were found in municipalities belonging to the greater Athens area in 1911, declining progressively during the study period and disappearing in 2011. Analysis of historical information sources illustrates the progressive disappearance of the olive groves in the greater Athens area over the last three centuries (Figure 4.20), following uneven urban expansion between 1830 and 2015 (Kallis 2010). Up to the early 1900s, the olive landscape 1-2 km west of Acropolis, central Athens, including the district of 'Eleonas' (in Greek 'olive groves'), has resisted to urban expansion and light industrialization under the Kifisos river. Compact urbanization afterwards has negatively impacted the extension of olive crop in the area, bringing to the disappearance of olive groves in the late 1970s. Ornamental olive trees and a small parcel devoted to olive crop in an experimental site still persist in the few 'urban voids' left out by dense urbanization in the area and are considered the last remnants of the large-size olive cultivation in Eleonas.

Similar dynamics were observed, even in more recent times, in municipalities of the greater Athens area where compact urban expansion has reduced the total surface of olive groves. Since the early 2000s, agriculture has been a residual component of the greater Athens landscape, previously devoted to olive groves, vineyards and garden crop, as official statistical data and farmers' interviews reveal. However, olive groves have persisted in some areas while competing for land with urban expansion. In this regard, it was demonstrated that dispersed urbanization was consuming preferentially other types of cropland (e.g. horticulture) than olive groves, contrary to compact urbanization (Colantoni et al. 2017). A specific focus on three fringe districts (Acharnes, Maroussi, Irini) located in the Greater Athens area was presented in the following paragraph based on a comparative analysis of ortho-photographs referring to the last decades.





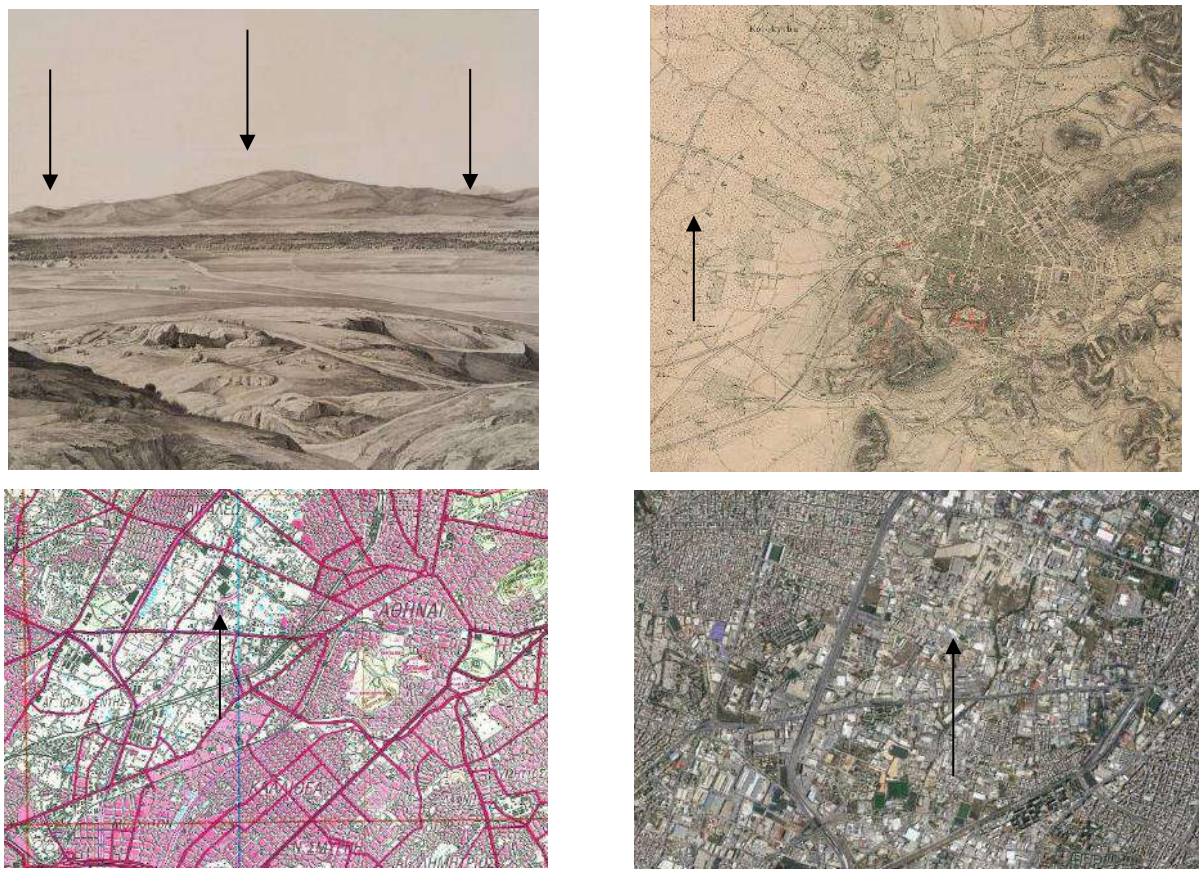


Figure 4.20. The olive groves west of Athens (including the so called 'Eleonas' district, see arrows) over the last three centuries: (upper left) a 1754 map taken from the Piraeus' municipal library; (upper right) a map dated 1785 by B. du Bocage; (middle left) an iconic representation of olive groves from the Archeological Park of Athens by Stadermann (1841); (middle right) the Kaupert map dated 1895; (lower left) a particular of the 1977 (1:50,000) map of the Hellenic Cartographic Military Service; (lower right) an aerial view of the area taken from Google Earth software referring to 2016. Source: own elaboration.

Figure 4.21 illustrates the occurrence of peri-urban olive groves in these representative sites of the Athens' urban fringe. Results of the field survey outline the persistence of a mixed landscape formed by olive trees and dispersed residential settlements. Land-use dynamics in these districts have demonstrated how peri-urban areas and olive landscapes have sometimes transformed into a fragmented agricultural-urban use of land, with increasing ecological disturbance to relict agro-forest systems. However, according to statistical data, olive tree surfaces were quite stable or even increasing in peri-urban municipalities. Moreover, despite a (more or less) sparse increase of urban settlements (e.g. in Acharnes), olive grove density has also intensified in specific areas along the Athens' fringe (Colantoni et al. 2016).

Figure 4.21. Peri-urban olive groves surrounding low and medium-density settlements in the Athens' fringe (left: 2004, right: 2016); upper panel: Acharnes, middle panel: Maroussi, lower panel: Irini). Source: elaboration of Google Earth imagery.

4.4.3. Sustainable land management for 'crisis' cities

Agro-biodiversity assumes a role in maintaining structure and functions of rural landscapes (Farina 2000). The richness of natural, semi-natural and cultivated habitats defines complexity, stability, ecological connectivity and quality of such agro-ecosystems (Paetzold et al. 2010; Raudsepp-Hearne et al. 2010; Orsini 2013). The work in Cecchini et al. (2018) aims at demonstrating that olive crop can be considered a traditional landscape system with potential for multiple uses and supporting a sustainable management of land resources in both rural and peri-urban ecosystems. In this regard, the intimate relationship between 'olive landscape' and urban expansion will be discussed. A final part of the chapter is devoted to policy implications of the empirical results achieved. Potential for multiple use of land is discussed from different points of view - environmental, societal and economic -, trying to infer empirical evidence from the study area to more general contexts in Mediterranean Europe (Briassouli 2008). As a matter of fact, olive production in Greece, as well as in other southern European countries, often plays an important role in the regional economy (Kosmas et al. 2016). When combined with livestock and forestry olive cropping increases and stabilizes agricultural production through better and more varied use of natural and human resources (Karamesouti et al. 2015). Olive groves are also characterized by a a small number of pests, tolerance to pest damage and abundant insect fauna contributing to biodiversity conservation (Calabrese et al. 2012).

Finally, olive crop in peri-urban areas provides additional ecological benefits with the mitigation of wildfire risk. According to Mitsopolous et al. (2015), the wildland-urban interface fire problem

appeared over the last 30 years in Greece, when a certain number of large fires destroyed many residential structures in the north-eastern suburbs of Athens. In this regard, olive tree is more resistant to fire than other species typical of Mediterranean ecosystems such as Maritime pine and Stone pine (Catry et al. 2006), which are much more sensitive to fire due to the presence of wood resins (Moriondo et al. 2008). Taken together, these considerations outline how olive groves contribute to ecosystem stability and mitigation of human pressure in peri-urban areas, contributing to ecological stability through soil protection and high-quality water conservation (Makhzoumi 1997). In this regard, transformation of fringe landscapes towards low-quality agricultural and pasture land and fragmented forest patches is potentially unfavorable for environmental quality and ecological fragility of fertile soils (Economidou 1993; Salvati and Ferrara 2014; Colantoni et al. 2015).

Concerning the socioeconomic issues associated with the 'olive landscape', the growing number of alternative food networks is considered a positive challenge for peri-urban districts and is connected to the Von Thünen approach based on the advantages of market proximity (De Zeeuw et al. 2011). Although in this model farmers must invest more and work harder to balance urban pressure facing the high value of the land near cities, the case of olive crops in Mediterranean cities does not confirm this general pattern (Moissidis and Duquenne 1997). By contrast, moderate agronomic treatments (e.g. mild soil amendments, moderate irrigation and mechanization, few chemicals) have a positive effect on the productivity of olive trees in small peri-urban farms held by less experienced (or non-professional) farmers. Additional benefits derive from farmer's multiple activities (e.g. agro-tourism, biomass and energy production, environmental education), typical of farms dominated by olive crop, and the reduction of conflicts with neighbors (e.g. population living in residential settlements close to olive groves) because of reduced fertilization treatments (Salvati et al. 2015). Olive tree needs limited works for pruning and fertilization; in this regard, multi-active peri-urban farmers are more oriented to invest on crops, such as olive, that need less agronomic inputs (Giourga and Loumou 2006).

Based on joint environmental and socioeconomic considerations presented above, a multifaceted process of landscape 'co-evolution' between discontinuous residential settlements and olive groves in peri-urban districts has been observed in the study area, producing a mixed use of land that influences natural ecosystems and local communities. The resulting landscape mosaic has potentiality to preserve traditions, cultures and biodiversity (Colantoni et al. 2017). Urban and rural elements co-exist in rapidly expanding peri-urban districts that implicitly maintain a large proportion of olive groves, characterizing mixed, high-quality landscapes (Moissidis and Duquenne 1997). While strictly urban models are represented by residential, commercial and industrial settlements in central cities, the rural component characterizing the metropolitan interface of several cities reveals a latent choice to maintain olive groves for self-consumption or small-scale economic production (Palazzo and Aristone 2017).

With on-going urban expansion, the Attica's landscape has experienced soil consumption and transformations of rural areas producing negative environmental externalities (Orsini 2013). However, olive groves and active, small-scale tree crop farming plays a role in buffering urbanization, representing an indirect response to discontinuous expansion of settlements and infrastructures (Ferrara et al. 2014). Compared with other crops (e.g. annual crops and grape), the results in Cecchini et al. (2018) have confirmed that olive trees expanded into fringe land, maintaining important crop surfaces in more distant rural areas. More specifically, areas destined

for olive crops decreased only in the most compact part of the greater Athens area, revealing a similar tendency with other rural productions, paralleling the decline in agricultural areas driven by inherent processes of dense urbanization. In respect to other cropping systems, olive groves preserved in some peri-urban districts lead to a durable presence of natural landscapes in metropolitan contexts (Recanatesi et al. 2016). This phenomenon is particularly relevant in the eastern district of Attica, where the most intense processes of suburbanization have recently occurred (Zambon et al. 2017).

Another characteristic that makes the olive agro-system particularly resilient to human pressure is the general small size of the land parcel suited to olive crop, especially under a progressive, statutory increase of the minimum lot size for building (Salvati et al. 2015). The out-of-plan settlements of Attica were declared a ZUDC (Zone of Urban Development Control) according to the National Law no. 1337/1983 with the aim to control land development in urban fringes and to prevent peripheral land around towns and cities from further transforming into urban areas. In these areas, the minimum lot size was increased from 0.4 hectares to 2 hectares, making the land parcels devoted to olive groves no more interesting for building and consequently less exposed to clearcutting or illegal fire for speculative building interests (Giannakourou 2005). Moreover, with recent changes in the Athens' socioeconomic context, building activity was progressively declining because of the 2007 financial crisis (Salvati et al. 2013). Fragmentation of land parcels (with increasing variability in size and shape (Pili et al. 2017) which makes them less valuable for selling), is a common phenomenon in the Mediterranean basin (Salvati et al. 2015).

Land fragmentation also reflects cultural behaviors such as the legacy of family farmers who "seem to be less inclined than ever to actually withdraw from farming unless they are approaching retirement and lack a successor, and recent studies reveal a remarkably strong attachment to continuing to keep the family name on the land and a reluctance to contemplate leaving the industry altogether" (Bonhet et al. 2003). Such considerations apply especially to family farmers; new farmers - usually preferring more profitable crops - do not have the same intergenerational time perspective as family farmers (Orsini 2013). The factors that contribute to the permanence of the olive oil short chain derive mainly from the self-consumption need, the willingness to exploit the sales' channels approaching tourists in the area, even within a negative perspective on 'hobby' olive farmers, asserting that these farmers are "cut off" from benefits and subsidies and, consequently, are more inclined to land abandonment (Kizos and Vakoufaris 2011). Together with the environmental, agronomic and economic benefits mentioned above, olive groves constitute a key element in peri-urban landscapes acting as a mitigation buffer of social conflicts, because multi-functional activities linked with olive crop may assume an important 'local community' value, not only in strictly rural areas, but also in peri-urban districts with less (and decreasing) workers employed in the primary sector (Salvati et al. 2015). The results are in line with the most recent characteristics of a typical post-productive phase of the agricultural sector in Europe (Kristensen et al. 2001), reflecting the recently introduced greening measures in the EU agricultural legislation, the greater awareness of the environmental impact of agriculture and a progressive increase in the number of part-time and hobby farmers with limited involvement in full-time agricultural activities, especially in metropolitan regions.

A thorough reflection on the persistence of olive groves in Mediterranean peri-urban landscapes can be proposed from the evidence collected in the work in Cecchini et al. (2018) and in earlier

studies (Salvati et al. 2015). Persistence of historical landscapes has become a key matter in southern Europe (Biasi et al. 2015). In this regard, olive tree cultivation, its spatial diffusion and crop variability, and the most general landscape features associated with this landscape system, are approaching a new developmental stage (Palazzo and Aristone 2017). Urbanization, new attitudes of farmers, mechanization and other effects linked with the disappearance of full-time farmers and large-size farms have contributed to shape the countryside around cities (Duvernoy et al. 2018), transforming the socioeconomic status of landowners and the profile of the customers interested to invest in an olive oil short chain (Salvati et al. 2015). In addition, climate change and economic instability contribute to the inherent differences between urban landscapes with intense industrialization and compact urbanization and mixed urban-rural landscapes with resilient 'cultivation patches', involving inevitable trade-offs between land profitability and rural identity (Palazzo and Aristone 2017).

At last, peri-urban landscape conservation is also linked to economic factors that can affect the welfare condition of farmers (e.g. increase of farmer's income, decline in mechanization investments, production savings). From this point of view, the mechanization of some crop operations, especially harvesting, contributes to the achievement of the objective of environmental sustainability and economic viability of farms specialized in olive cultivation (Almeida et al. 2016). In fact, following Famiani et al. (2014), a wide range of machines is available on the market, from inexpensive electric or pneumatic facilitators to actual harvesting machines. Besides a reduction in harvesting costs, the use of these machines involves an improvement in operator safety, without affecting the product quality. The opportunity of using machines to harvest olives and gain high quality oils would also make it easier to preserve historic peri-urban landscapes with a high social and environmental value in the Mediterranean basin. However, an increased mechanization of peri-urban farms should also consider the possible conflicts with neighboring settlements in terms of land-use conflicts, noise and traffic constraints.

As a local advantage of economic and symbolic importance, the oil production and the corresponding olive landscape can finally represent a reliable socio-environmental added value for peri-urban economically-disadvantaged districts (Kizos and Vakoufaris 2011). Safeguarding rural ecosystems is a crucial topic in the sustainable land management of suburban areas (Salvati et al. 2015). In this regard, Farmland Conservation Strategies can integrate specific measures aimed at (i) preserving rural land from soil sealing, (ii) containing urban expansion and informal development and (iii) protecting relict natural landscapes. Local governments are increasingly required to develop land-use plans incorporating measures for sustainable agriculture, nature conservation and promotion of alternative goods in local markets (Olsson et al. 2016), based on the preservation of typical crops, such as the olive tree.

A comprehensive investigation of structure and functions of peri-urban landscapes dominated by olive crop contributes to a full understanding of the history of human-nature interactions in the Mediterranean region. Such approach should refer to evolving landscape elements over a long-time span. In this regard, the work in Cecchini et al. (2018) explores a complex issue involving socioeconomic and ecological topics (Marchetti et al. 2014), justifying the use of a multi-disciplinary framework aimed at unraveling the intimate relationships between the 'economic' sphere and the 'ecological' factors in peri-urban areas with 'high social density' (Brunori and Rossi 2007) and multifaceted environmental feedbacks. Based on this framework, territorial variability, topographic

complexity and urbanization-driven land fragmentation are a relevant challenge for politicians, policy makers and land managers.

Regarded as a crop adapted to poor soils and dry Mediterranean climate, olive groves were increasingly cultivated in marginal and fragmented land at the fringe of metropolitan regions, replacing more economically-viable crops. These transformations were producing a heterogeneous, diversified and confused landscape, with natural elements frequently intermixed with discontinuous urban settlements (Duvernoy et al. 2018). Assessing short-term trends in olive's cultivated area is particularly relevant in the light of sustainable use of natural resources in peri-urban regions, since olive requirements in soil and water are relatively modest. This aspect is of great interest when olive groves are replacing irrigated crop systems, since these high-input systems are causing negative consequences in terms of water demand and land depletion in peri-urban land, with increasing conflicts for soil and water resources. Regional transformations impacted (both positively and negatively) socioeconomic systems; the resulting environmental conditions required extensive monitoring from the socio-ecological perspective. In this line of thinking, landscape transformations can be more effectively governed by multi-level policies incorporating short-term and long-term socioeconomic targets.

4.5. Recent dynamics in the Mediterranean urban fringe

Urbanization-driven land take exerts serious environmental pressures on agricultural landscapes worldwide, particularly in peri-urban areas, and is molded by social forces associated with residential development, demographic change, economic growth, and improvements in infrastructures and transportation. Policy strategies and planning instruments aimed at containing agricultural land consumption usually adopt specific approaches, based on the intimate characteristics of target areas. Zoning approaches may draw on information dealing with land-use transitions and their detrimental role altering the functionality of soils, water balance, or habitat quality at specific locations (Nuissl et al., 2009). Results of earlier studies showed that rapid expansion of built-up areas in metropolitan regions of economically-advanced countries led to accelerated land-use conversion, determining land abandonment and a consequent loss of cropland (Wu and Zhang, 2012).

Transformation of agricultural landscapes are widespread land-use changes in temperate regions, leading to crop intensification (or land abandonment) at certain locations and a growing dependence on other world regions for many agricultural products. Natural conservation policies and socio-demographic transitions leading to accelerated internal migration, e.g., from rural to urban areas, are intrinsic forces contributing to shape such dynamics. The socio-environmental outcomes of land abandonment/recovery and the potential for agricultural intensification (or extensivation) hinge on incomplete knowledge about the spatial patterns of farmland transformations at the regional scale, the related driving forces, and the underlying socioeconomic context at the local scale. A comprehensive assessment of different use of rural land-including abandoned cropland and recovery of previously abandoned farmland-forms a basis for assessing the environmental outcomes of different agricultural practices and the potential of unused land for food production, bioenergy, and carbon storage (Boubaker et al., 2016; Delfanti et al., 2016; Colantoni et al., 2013; Marucci et al., 2018; Marucci et al., 2017; Zambon et al., 2016; Estel et al., 2015), also evidencing the role of imperfect local markets, technological backwardness, farmholder's inaction, and the impact of economic crisis on local agricultural productions.

Cited article

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Fallow land is a specific use of rural land. Being a consolidated and environmentally-friendly agronomic practice, set-aside is sometimes associated with specific cropland (e.g., cereals) and defined characteristics of entrepreneurs. Set-aside land was shown to be an effective way to improve soil chemistry and increase biodiversity on arable farmland. In this regard, as a result of set-aside practices, fallow land is commonly defined as a farmland ploughed and harrowed but left for a period without being sown-to restore its fertility or to avoid surplus production. Set-aside has been extensively subsidized within the European Union (EU) Common Agricultural Policy framework. Subsidies to set-aside were introduced by the European Economic Community in 1988 (Regulation No. 1272/88), with multiple objectives dealing with both economic targets and environmental benefits-following considerable damage to agricultural ecosystems and wildlife as a result of the intensification of many agricultural systems. Set-aside became compulsory in 1992 for large arable farmers as part of the MacSharry reform of the Common Agricultural Policy. The European

Commission reduced the set-aside requirement to 0% in 2008, agreeing to abolish set-aside through the Common Agricultural Policy (CAP) Health Check.

In a continuous effort to make agriculture more environmentally-friendly and socially sustainable, agri-environmental schemes have been introduced as part of European Union's (EU) Common Agricultural Policy and are now a key issue in any strategy of rural development (Kuemmerle et al., 2015). Methodological approaches to analyze agri-environmental schemes include the use of specific indicators of rural development, concentrating on sustainable agronomic practices and land-use. The ratio of fallow land in total arable land or in total utilized agricultural area is considered a relevant agri-environmental indicator, and a higher percentage of fallow land in a rural landscape may reflect (more or less intense) processes of agricultural extensivation, contributing to distinguishing "performance" effects (e.g., agricultural practices) from "outcome" effects (e.g., environmental impacts) under specific subsidy regimes. Change in the extent of fallow land is considered an implicit indicator of land-use intensity at the regional scale (Kuemmerle et al., 2015). Diachronic agri-environmental indicators evaluating trends over time in fallow land at farm and district (i.e., local) scale also provide basic information on change (or maintenance) of traditional land-use and place-based agricultural management practices.

While the extent of fallow land is particularly high in traditional farming systems-especially under poorly or moderately fertile soils and at higher elevation (mountain or upland districts)-fallow land are also relatively common in peri-urban contexts. In this regard, subsidies to set-aside and other economic incentives to ecologically-friendly agronomic practices are considered particularly important in fragmented environments typical of metropolitan regions where relevant land-use conflicts exist and consolidate over time (e.g., thanks to the expansion of both residential and service settlements). Experiencing opportunities and constraints typical of fringe districts, peri-urban farms are increasingly required to cope with both economic targets (i.e., improving agricultural productions in both quantitative and qualitative terms) and environmental targets (e.g., providing ecosystem services for local communities and the surrounding cities), in a context where pressure for land is particularly high (driven by real-estate speculation and planning deregulation) and where fertile soils are progressively abandoned thanks to latent socioeconomic forces underlying urban sprawl.

A sustainable land management strategy for metropolitan regions is increasingly required to quantify long-term and short-term land-use changes, identifying trends in relevant driving factors (Primdahl et al., 2003; Colantoni et al., 2015; Tanrivermis, 2003), with special regard for cropland-being largely consumed by urban expansion. Due to multifaceted social processes, landscape transformations in advanced economies involve several interacting actors (Garcia Latorre et al., 2001). Since the early 1980s, European Mediterranean cities have experienced a rapid transition from mostly compact and dense models to various steps of a more discontinuous morphology characterized by huge expansion around inner cities (Schneider and Woodcock, 2008). Trends toward "compact growth" observed up to the early 1990s and the following "discontinuous urbanization" have affected land-use structure and peri-urban farming in a different way (Colantoni et al., 2016), reflecting a spatially-varying rate of land consumption and high impact on specific cropping systems. How the changing use of land represents a target for policies mitigating soil consumption has been discussed in earlier studies (e.g. Ceccarelli et al., 2014). However, empirical evidence from different socioeconomic contexts is still necessary to identify the latent relationship

between urban growth, peri-urban farming and transformation of rural landscapes in Mediterranean fringes.

Based on these premises, fallow land dynamics over a relatively long time period characterized by different subsidies' regimes-together with basic information on total cropland increase or decline-was considered a useful indicator to infer latent transformations in peri-urban landscapes and to propose strategies that may promote peri-urban agriculture and/or preserve relict cropping systems. While being largely influenced by the related subsidies' regime, fallow land is considered an element of peri-urban landscapes possibly associated with specific characteristics of the regional economic structure and the local community. In such contexts, it was hypothesized that fallow land increased in size over the study period together with direct payments to farmers (EU subsidies), declining rapidly in the most recent transitional phase of rural development, with subsidies oriented mostly to fulfil environmental targets. The work added to this assumption hypothesizing that fallow land is (i) an additional stock of economic value (depending on the intensity of land speculation and the flexibility of regional planning systems, allowing-or preventing-change in zoning rules that authorize conversion to urban use), or (ii) a stock of rural land immediately available for crop intensification. Considering the transition from economic expansion to crisis, the present work focuses on the Athens metropolitan region (Greece), investigating regional-scale cropland dynamics and long-term trends in fallow land area in a peri-urban landscape dominated by traditional crops-mainly olive-and progressively threatened by urban sprawl. A spatially-explicit analysis of the distribution of fallow land at municipal scale complemented this work, analyzing the background socioeconomic context at the same spatial scale as a possible factor of landscape change. Athens was regarded as a paradigmatic Mediterranean city (Arapoglou and Sayas, 2009; Di Feliciantonio and Salvati, 2015; Maloutas, 2004), with long-term development processes being representative of both "compact" and "dispersed" waves of urban expansion (Carlucci et al., 2017; Chorianopoulos et al., 2010; Chorianopoulos et al., 2014; Rontos et al., 2016; Souliotis et al., 2013; Zitti et al., 2015). By considering fallow land together as a proxy of agricultural intensification/extensivation and as an indirect indicator for the increasing pressure of real estate speculation on rural land, the study sheds further light on latent processes of urban growth and agricultural recovery/decline at the fringe of a large Mediterranean city over sequential economic expansions and recessions. In this regard, economic downturns may shape the socioeconomic context, influencing rural land-use and farmland characteristics in a different way, e.g., stimulating rural land-use over time periods when building activity is depressed thanks to economic crisis. Empirical findings of this study may provide a relevant knowledge base to understanding latent mechanisms of landscape transformation in other European contexts with similar ecological and territorial characteristics.

4.5.1. Land-use indicators and data analysis (1970-2015)

According to the standardized definition of metropolitan areas in Europe proposed by the Urban Atlas initiative (Gospodini, 2006), the Athens' metropolitan region was selected as the study area (Zitti et al., 2015). The area is the most densely populated in Greece (more than 4400 inhabitants/ km^2 in 2011) and population density has increased nearly 2900 inhabitants/ km^2 between 1951 and 2011. Since the early 1980s, the area experienced suburbanization with a progressive expansion of discontinuous fringe settlements (Chorianopoulos et al., 2010). Rural districts of Messoghia and Thriasio were especially involved in a subtle process of metropolitan expansion driven by real estate speculation and public/private investments during the Olympic Decade (Chorianopoulos et al.,

2014). Since the late 2000s, Attica has experienced an intense economic recession (Kaika, 2012). Combined with austerity urbanism and neoliberal policy reforms, recession determined diffused unemployment and job insecurity, income decline, poverty and social unrest (De Rosa and Salvati, 2016; Gkartzios et al., 2017). As a side effect of recession, moderate counter-urbanization was observed, fueling "back-to-the-land" social movements (Gkartzios et al., 2015).

Statistical data aggregated at the prefectural or regional scale were considered to assess the distribution of different types of cropland in the Greater Athens' area, rural Attica, Attica, and Greece between 1970 and 2015. Municipalities were selected as the elementary spatial domain for more detailed analysis over a shorter time interval (1993-2015). Information on the dominant agricultural land-use at the municipal scale were derived from official statistics provided by a comprehensive agricultural survey held every year in Greece by the Hellenic Statistical Authority (hereafter ELSTAT) and quantifying land-use (annual crop, tree crop, and fallow land) at the municipal scale since 1993. This data source may provide a comprehensive outlook of recent transformations of the agricultural landscape in the area, giving specific information on rural land-use and the main agricultural practices. Two indicators (utilized agricultural area in total municipal area and fallow land in total agricultural land) were calculated at the selected spatial scale and at three different dates (1993, 2006, and 2015) with the aim to define the possible impact of economic expansion (before 2006) and recession (after 2006). The percentage of fallow land under economic subsidies (mainly under the European Common Agricultural Policy framework) was also derived from the same statistical source for the year 2015. A map illustrating the progressive loss of cropland from each municipality of the study area was prepared indicating the year when the complete disappearance of agricultural land (e.g., due to urban expansion) was observed. Twelve additional background indicators assessing basic characteristics of the socio-demographic context (population density, forest land in total landscape, per-capita built-up area, distance from Athens, Piraeus, Maroussi, Markopoulo Messoghias, municipal area, per-capita declared income (log-scale), share of inhabitants living and working in the same municipality in total population, share of population residing in the same municipality five years before the census in total population, and share of non-native population born in total resident population) were derived from official statistics mainly based on ELSTAT censuses and public registers.

The spatial distribution of the adopted indicators was analyzed using maps and descriptive statistics. A non-parametric statistical approach was developed to analyze land-use and background indicators adopted since most of the variables considered in this study display relevant deviations from normality. A cluster analysis based on a two-way joining procedure was run on two standardized indicators (agricultural utilized area to total municipal area and fallow land to total agricultural utilized area) at three time points (1993, 2006, and 2015) with the aim to identify similarities and changes in the spatial distribution of total cropland and fallow land over time, contributing to identify latent patterns of rural land-use and farmland transformations. Municipalities were regarded as the elementary analysis' domain. Two-way joining is probably one of the most commonly-used multivariate (non-parametric) techniques under the hypothesis that both cases and variables will simultaneously contribute to the uncovering of meaningful patterns of clusters. Two-way joining analysis produces a graph ordering cases (municipalities) and variables (land-use indicators) based on similarity/dissimilarity patterns. The graph also indicates a standardized score (with zero-average score) for each case and variable using different colors. Such

a graph contributes to identifying specific clusters based on similar (negative or positive) scores for a defined group of variables and cases.

The difficulty when interpreting results from this technique may arise from the fact that similarities between different clusters may pertain to (or be caused by) somewhat different subsets of variables, leading to the assumption that the resulting structure (clusters) is, by nature, heterogeneous. To investigate the impact of spatial heterogeneity on clustering structures, a non-parametric correlation analysis based on pair-wise Spearman co-graduation coefficients was run between the land-use indicators mentioned above and a set of background indicators at the same spatial scale (municipalities). Spearman coefficients range between 1 (the highest positive correlation) and −1 (the highest negative correlation) with 0 indicating absence of both linear and non-linear correlation between variables. Significance was tested at $p < 0.05$ after Bonferroni's correction for multiple comparisons. Spatial units (municipalities) where cropland disappeared before 1993 (e.g., urban areas, such as the municipalities of Athens and Piraeus) were excluded from both analyses (two-way clustering and Spearman correlations).

4.5.2. Trends of rural land-use in Attica

Table 4.14 illustrates trends over time in total cropland and specific land-use between 1970 and 2015 in the study area, distinguishing urban from rural districts. In the Greater Athens' area-a consolidated urban area around the central cities of Athens and Piraeus-cropland extended 4.2% of total land in 1970 and declined to 0.1% in 2006 and 2015. Arable land accounted for 20% of cropland in 1970 decreasing to around 1% in mid-2000s. Garden crops decreased considerably (from 39% to 21% over the study period); vineyards were relatively stable around 4%, although with a temporary increase to 12%-13% in the late 1990s and mid-2000s. Tree crop increased considerably from 12% (1970) to 74% (2015). Percentage of fallow land in total cropland doubled between 1970 and 2006; nearly half of cropland was managed as fallow land in 2006. This percentage declined substantially in the last time interval, reaching 0% in 2015.

Rural Attica experienced a strong decline in total cropland. The percentage of cropland in the total landscape halved during the study period (42.5% in 1970; 20.2% in 2015). The proportion of arable land and garden crops in total farmland remained substantially stable over time; vineyards decreased moderately over the same time period. The most relevant changes in the Attica's agricultural landscape involved tree crop, increasing continuously over time from 23% (1970) to 53% (2015). Fallow land remained quite stable up to 2006, with proportions in total cropland ranging between 30% and 36%. In 2015, fallow land accounted for only 10% of total cropland in rural Attica. Similar dynamics were observed in the whole of Attica. In Greece, cropland decline was relatively milder, moving from 31% of total land (1970) to 25% (2015). Being the dominant agricultural land-use in Greece, arable land decreased by nearly 10% over the study period (from 61% in 1970 to 52% in 2015). Garden crops were substantially stable, and vineyards decreased moderately (from 5% in 1970 to 3% in 2015). Tree crop increased continuously, passing from 17% (1970) to 31% (2015). Finally, fallow land decreased moderately from 13% (1970) to 11% (2015) showing a substantial stability between 2006 and 2015. This evidence outlines that decline of fallow land during the last economic recession in Greece was a phenomenon specifically observed in peri-urban areas, and more specifically in the Athens' metropolitan region. This phenomenon was coupled with more

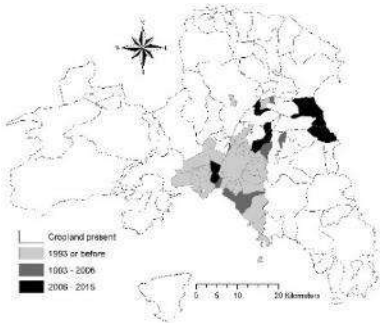
general, long-term trends of agricultural extensivation (increase in tree crop, mainly olive) and local-scale specialization.

Table 4.14. Long-term trends in cropland and fallow land by land-use class in various geographic districts, Greece 1970-2015.

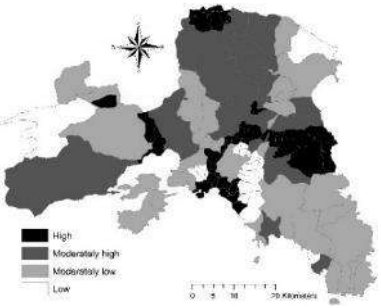
Year	Total Crops	Arable Land	Garden Crop	Vineyards	Tree Crop	Fallow Land	Total Crops	Arable Land	Garden Crop	Vineyards	Tree Crop	Fallow Land
	Greater Athens' area						*Rural Attica*					
1970	4.2	19.9	38.6	4.4	12.3	24.8	42.5	22.0	5.4	16.6	22.8	33.2
1979	3.2	15.6	35.0	4.2	18.7	26.4	39.6	19.5	4.7	17.1	26.5	32.2
1988	2.9	12.3	28.0	3.2	16.1	40.5	38.3	18.7	6.0	15.5	29.2	30.6
1997	2.2	14.6	5.6	12.0	32.1	35.6	38.0	14.6	5.6	12.0	32.1	35.6
2006	0.1	0.9	25.8	13.2	12.2	47.9	29.6	13.8	7.6	9.6	34.7	34.3
2015	0.1	1.3	20.5	4.3	73.9	0.0	20.2	18.5	6.0	12.2	53.2	10.0
	Attica as a whole						*Greece*					
1970	28.9	22.0	5.8	16.4	22.7	33.1	30.9	61.9	2.6	5.4	16.6	13.4
1979	26.9	19.4	5.2	16.9	26.4	32.1	31.0	60.0	2.8	4.8	19.6	12.8
1988	26.0	18.6	6.4	15.3	29.0	30.7	30.4	59.0	2.8	4.1	22.3	11.8
1997	25.7	14.5	5.8	12.0	31.9	35.8	29.8	57.6	3.1	3.4	24.4	11.5
2006	19.8	13.8	7.7	9.5	34.7	34.3	28.5	55.3	3.0	3.4	26.9	11.4
2015	13.5	18.5	6.1	12.2	53.2	10.0	24.9	52.9	2.1	2.9	31.0	11.2

Figure 4.22 illustrates the spatial distribution of selected land-use indicators in the study area through maps. A specific district corresponding with the Greater Athens' area was identified where cropland has disappeared before 1993. This area-including the central cities of Athens, Piraeus, and the surrounding municipalities-was heavily urbanized since the early 1950s and reached the highest population concentration in the 1970s (with density approaching 15,000-20,000 inhabitants per km^2) and the complete saturation of open spaces in the late 1980s. A circular fringe district around the Greater Athens' area was progressively involved in a process of land conversion from agriculture to residential settlements. The left, top map illustrates the progressive disappearance of cropland from fringe municipalities northeast of Athens between 1993 and 2015, including some coastal areas situated in Eastern Attica prefecture further away from Athens (Rafina, Nea Makri). These areas were originally devoted to cropland and are well connected to the most traditional agricultural districts of Messoghia and Marathon.

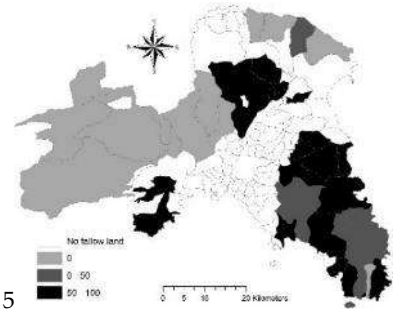
The spatial distribution of the most stable agricultural areas in the Athens' metropolitan region also reflects soil quality. The lowest proportion of cropland conversion to built-up areas was observed for high- or medium-quality soils, mainly observed in flat districts of Marathon, Messoghia and Keratea (Eastern Attica), Oropos (Northern Attica), and Thriasio/Megara (Western Attica). Thriasio and Megara were districts specialized in traditional cropland (olive, vine, wheat) since antiquity. Cropland in 1993 was characterized by a rather homogeneous, radial distribution around the Greater Athens' area (middle left map). More than 10 years later, cropland declined in Thriasio and Messoghia, two traditional rural districts in Attica particularly exposed to urban sprawl thanks to the infrastructural development typical of the Olympic period (e.g., the new international Airport in Spata and the Attiki motorway in Messoghia, the new railway deposit, and the new national motorway in Thriasio). In 2015, cropland decline was evident in remote rural districts in Northern Attica (Oropos) and Western Attica (Megara). These areas are less exposed to sprawl but relatively well accessible from the central city.



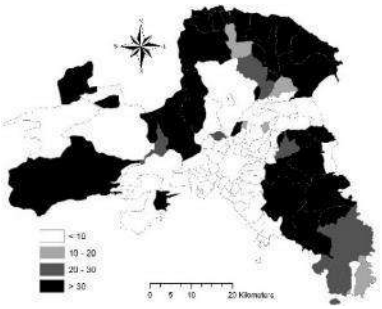
Year of cropland disappearance



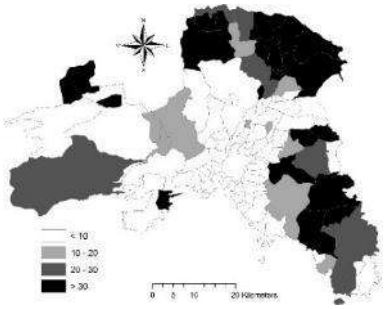
Soil quality



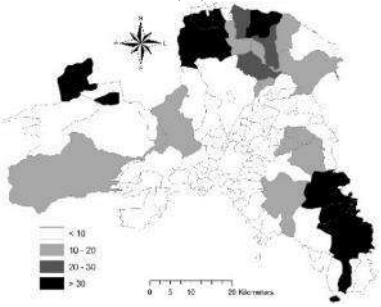
Subsidized land in total fallow land (%)



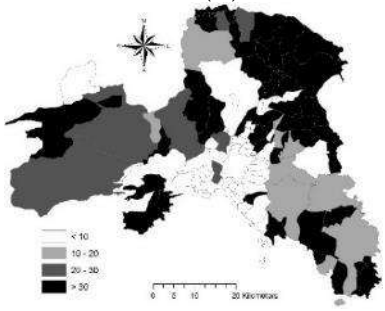
Cropland in total municipal area, 1993 (%)



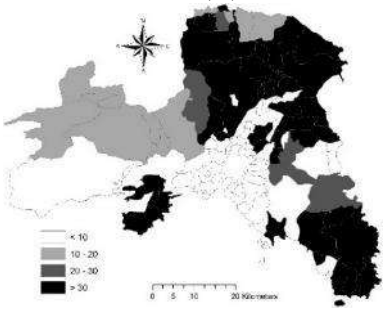
Cropland in total municipal area, 2006 (%)



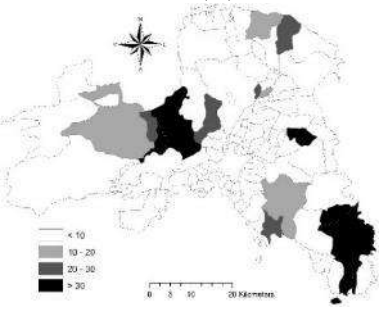
Cropland in total municipal area, 2015 (%)



Fallow land in total cropland, 1993 (%)



Fallow land in total cropland, 2006 (%)



Fallow land in total cropland, 2015 (%)

Figure 4.22. Spatial distribution of selected indicators in the study area.

The spatial distribution of fallow land followed only partly the pattern described above for total cropland. In 1993, the highest percentage of fallow land in total cropland was observed in marginal rural districts of Attica (Salamina, Oropos, and Thriasio) and in some fringe municipalities north of Athens (Ano Liosia, Kifissià, Maroussi). Maintaining a stable share in total cropland compared with 1993, fallow land concentrated in Salamina Island, Northern Attica (Oropos), and Eastern Attica (Messoghia) in 2006. In the last 10 years, fallow land decreased drastically all over the study area, except for Keratea/Lavrio district, Thriasio plain, and some sparse municipalities in Northern Attica (Oropos) and Messoghia (Koropi, Vari, Spata). The relationship between the percent change over time in total cropland and in fallow land followed a distinct pattern over the two studied intervals (Figure 4.23). The first-time interval reflects economic expansion (1993-2006) and was characterized by a positive relationship between the two variables (Spearman rank correlation, $r_s = 0.4$, $p < 0.05$, $n = 79$), indicating that the percentage of fallow land in total cropland was proportional to the percentage of cropland in total landscape. A more mixed and random pattern was observed during the subsequent recession period (2006-2015) when the relationship between the two variables was non-significant. This means that the proportion of fallow land changed over time irrespective of the total stock of cropland at landscape scale; such a pattern is a result of the progressive reduction in

subsidies to set aside. The share of fallow land receiving subsidies in total fallow land (2015) increased in areas less specialized in agriculture (e.g., Oropos in Northern Attica), or more exposed to urban expansion (e.g., Acharnes in the Greater Athens' area, Salamina Island, and Messoghia district in Eastern Attica), being considerably lower in areas traditionally devoted to specialized cropland with high economic value and less affected by urban sprawl (e.g., Megara in Western Attica, Marathon in Eastern Attica). In such context, findings suggest that fallow land may acted as an additional land stock. In the case of Athens, an increasing proportion of land was destined to crop production during crisis, mainly tree crop.

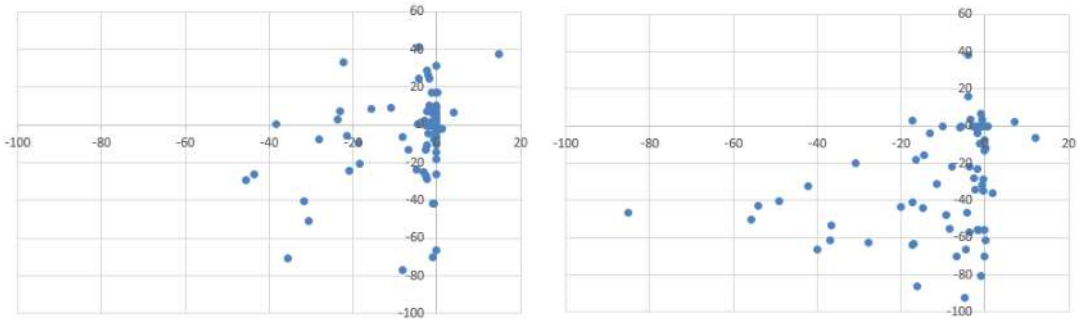


Figure 4.23. Relationship between percent change in cropland (y-axis) and fallow land (x-axis) in each municipality of the study area with at least 0.1 ha cropland in 1993 (left: 1993-2006; right: 2006-2015).

A specific analysis of processes of convergence (or divergence) over time between total cropland and fallow land in total landscape was based on a two-way clustering (Figure 4.24) that explores spatial trends of both variables at three time points (1993, 2006, 2015) over the study area. The same color in Figure 4.24 indicate a similar pattern between variables, characterized by values respectively below the average (green) or above the average (red). Fallow land in 2015 displays a divergent distribution in respect with the same variable in previous time points (1993 and 2006). These results confirm the empirical findings described. Fringe municipalities surrounding central Athens clustered at the top of the graph and were characterized by low standardized values (< −1) of the share of cropland in total landscape. More mixed clusters of municipalities were observed in rural Attica, where similar variables' ranks were observed for land-use indicators at 1993 and 2006 and dissimilar ranks between total cropland and fallow land were recorded for 2015. In other words, two-way clustering ordered spatial units along the urban-rural gradient in Athens, evidencing a strong similarity among peri-urban municipalities and a more mixed pattern for rural municipalities.

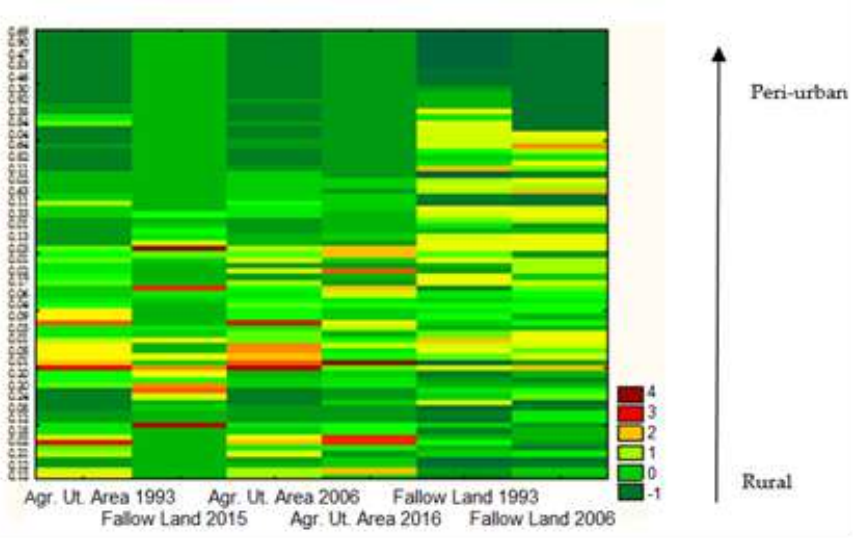


Figure 4.24. Results of two-way clustering by land-use indicators (columns) and municipalities (rows); the left rank indicates the share of built-up areas in total landscape for each municipality of the study area (colors illustrate the standardized value for each variable according to the legend on the right side of the graph).

Pair-wise correlations between land-use indicators and background variables were studied through a Spearman non-parametric analysis (Table 4.15) with the aim to identify the most relevant socio-demographic factors associated with a progressive decline of total cropland and fallow land over time. Total cropland decreased significantly with population density and increased with the distance from Athens, Piraeus, Maroussi, and with the proportion of workers living and working in the same municipality. A stable correlation profile was observed for the three study years. Additionally, total cropland increased with per-capita built-up area and decreased with per-capita declared income in 2015. In line with the spatial pattern observed for total cropland, fallow land decreased with population density for all years examined. A more specific correlation pattern was observed for 2015, when fallow land increased with forest land, per-capita built-up area, and distance from Athens and Maroussi. This pattern indicates that, after a crisis, fallow land concentrated in more remote, rural districts, where land profitability is lower; in more accessible rural districts fallow land declined rapidly during recession, irrespective of cropland decline; in such areas fallow land was more likely cultivated during a crisis, thanks to higher land profitability and the overall reduction of subsidies. Such dynamics may also reflect the intrinsic decrease in building activity in the last decade and the reduced pressure of land speculation associated with a negative peak in the real estate market. The share of subsidized fallow land in total fallow land decreased with the distance from Messoghia and with residential mobility (an indicator of urban expansion typically higher in Eastern Attica than in Western Attica), increasing significantly with per-capita declared income and the share of the non-Greek population native to Europe in the total resident population.

Table 4.15. Results of a Spearman rank correlation analysis (significant coefficients at $p < 0.05$ were shown).

Variable	Utilized Agricultural Area			Fallow Land in Total Cropland			Subsidized Land
	1993	2006	2015	1993	2006	2015	In Total Fallow Land
Population density	−0.60	−0.67	−0.74	−0.42	−0.47	−0.49	
Forests in total landscape						0.44	
Per-capita built-up area			0.74		0.48	0.46	
Distance from Athens	0.53	0.64	0.69			0.43	
Distance from Piraeus	0.50	0.60	0.64				
Distance from Maroussi		0.50	0.57			0.42	
Distance from Markopoulo Me.							−0.65
Municipal area		0.46	0.56			0.52	
Per-capita declared income (log)			−0.45				0.65
Self-contained workers	0.50	0.51	0.59				
Self-contained population							−0.60
Per cent rate of non-native population born in Europe							0.61

4.5.3. Fallow land, recession and socio-demographic local contexts

Landscape transformations were more intense in local contexts where resident population increased rapidly because of suburbanization and where ecosystems are more fragile due to specific land conditions (Aretano et al., 2013; Beriatos et al., 2004; Biasi et al., 2015; Biasi et al., 2015; Cimini et al., 2013; Cohen et al., 2015; Economidou, 1993; Kizos and Vakoufaris, 2011; Kristensen et al., 2001; Raudsepp-Hearne et al., 2010; Salvati, 2014; Serra et al., 2008; Tsilimigkas and Kizos, 2014; Vieri, 2002; Zambon et al., 2018). Attica's landscape experienced soil consumption and changes in rural areas producing negative environmental externalities. With economic crisis, a small, but increasing, number of residents in Greek cities (especially in Athens and Salonika) declared the willingness to leave their city with the aim to work in the agricultural sector (Orsini, 2013; Moissidis and Duquenne, 1997). Moreover, an earlier study on farmers' multiple activities in peri-urban districts of Attica stated that 40% of the household members who are of working age have declared to have two or more jobs, because peri-urban districts surrounding central cities offer more opportunities for alternative jobs than strictly rural areas (Orsini, 2013).

The empirical analysis carried out in this study contributes to distinguish the most urbanized contexts close to the Greater Athens' area from the rest of the metropolitan region. Athens has experienced one of the most rapid expansions of resident population, income, and settlements in Southern Europe (Orsini, 2013; Moissidis and Duquenne, 1997). A trend toward discontinuous urban expansion was observed since the 1980s (Gkartzios, 2013; Delladetsima, 2006; Giannakourou, 2006), with a prevalence of medium-low density settlements expanding along the sea coastline and in Messoghia district (Eastern Attica), following suburbanization processes (Cuadrado-Ciuraneta et al., 2017). With recent changes in the Athens' socioeconomic context, building activity declined markedly since the 2007 financial crisis (Serra et al., 2014).

The inherent modifications of the rural landscape in metropolitan Attica are strongly associated with the local socio-demographic context, possibly reflecting sequential cycles of economic growth and crisis. Fallow land was demonstrated to be a relevant element of this transforming landscape, being relatively stable over time in Attica. During economic expansion, fallow land increased

moderately or remained stable, despite a progressive decline in total cropland at the municipal scale. Together with other socioeconomic reasons, this pattern can be associated with the EU subsidy regime of direct payment to set-aside. In such a context, fallow land concentrated in fringe districts surrounding the Greater Athens' area, where agriculture competed more strongly with urban expansion.

During crises, fallow land decreased in more accessible rural areas coinciding with an inherent reduction in direct subsidies to farmers. In these areas, fallow land was sometimes converted to more productive crops, including vines and olives, as the official statistics at an aggregate spatial scale may indicate. This transition occurred despite strong accessibility to downtown Athens and high land prices-in many cases associated with a context of planning deregulation and ineffective/partial land cadaster. A marked decline in building activity and real estate speculation driven by recession was considered an indirect factor leading to productive transformations of rural landscapes that contain land conversion to urban use. While being directly affected by changes in the subsidy regime, results of this study suggest that both increasing tree crops and decreasing fallow land are indirectly associated with this building trend.

Considering the distinct dynamics that have characterized landscape transformations in Attica during the last economic expansions and recessions, fallow land was hypothesized to act as a land stock in the most recent decade, being available to both agricultural production and real estate speculation depending on economic downturns, planning flexibility and the specific subsidy regime. During economic expansion, fallow land increased thanks to direct payment to set-aside. At the same time, when building activity and land speculation were the highest, fallow land consolidated as a land stock, with some owners waiting for land zoning revisions-a frequent process in Greece, at least up to the early 2000s. Latent factors, such as poor effectiveness of town planning and expansion of unauthorized, and often illegal, buildings converted to legal settlements before political elections, contributed to this process. Conversely, fallow land in 2015 concentrated in less accessible, forest and upland districts further away from Athens. Under a progressively reduced subsidy regime, these districts were characterized together by slight increase in building activity and real estate speculation (possibly thanks to planned gains in road accessibility to Athens) and relatively low agricultural productivity. This specific pattern was confirmed by the spatial distribution of fallow land receiving subsidies in 2015, which was totally independent from the spatial distribution of fallow land in total cropland. Fallow land under subsidies hence concentrated in areas more exposed to real-estate speculation (e.g., Eastern Attica), while decreasing significantly in areas more specialized in agriculture (e.g., Western Attica), where land profitability is higher. Agro-environmental measures promoting more sustainable cropping systems may also contribute to this spatial pattern, being more relevant in rural areas with less intensive agriculture.

Together with cropland decline, the share of irrigated land in total cultivated land showed a small increase in rural Attica (from 8.8% to 13.1%), compared with the slight decline observed in the Greater Athens' area (from 3.9% to 1.7%) (Almeida et al., 2016; Calabrese et al., 2012; Famiani et al., 2014). This evidence outlines, at least for the last decade, an increasing polarization in economically-marginal rural land (with high rate of cropland abandonment, forestation, moderate human pressure, and urban sprawl) and highly-productive agricultural districts (with decreasing proportion of fallow land, stable cropland, a more intense conversion to tree crop systems, and reduced land speculation for alternative uses of land-including conversion to urban destinations).

These findings are in line with more general transformations of rural landscapes recently observed in Attica and in other Mediterranean urban regions (Gutierrez et al., 2009; Kizos, 2010, 2011; Loumou et al., 2003), including local-scale processes of agricultural intensification (increase in vineyards and garden crops and consequent decrease in arable land) or extensivation (expansion of tree crops, mainly olive groves). For instance, it was demonstrated how olive groves may buffer human pressure in peri-urban areas, contributing to ecological stability through soil protection and high-quality water conservation (Meneley, 2004; Palazzo and Aristone, 2017; Tanasijevic et al., 2014; Makhzoumi, 1997; Paetzold et al., 2010). Urban growth, rural development, new attitudes of farmers through irrigation, intensification, and mechanization, as well as more latent effects linked with the disappearance of full-time farmers and large-size farms, have contributed to shape the rural landscape around cities, with marginal land being more influenced by sequential cycles of economic expansion and recession (Duvernoy et al., 2018). In these regards, economic instability contributes to the inherent differences between peri-urban landscapes with intense industrialization and compact urbanization and mixed rural landscapes with resilient "cultivation patches", involving inevitable trade-offs among land profitability and rural identity (Newman et al., 2017).

Results of this study outline a sort of landscape "co-evolution" between urban expansion, economic cycles and peri-urban farming systems. Understanding how countryside cohabits with other uses of land along urban fringes is necessary since the current landscape can be recognized as an "agriburbia", where agricultural production is mixed with other uses (Sandul, 2010; Le Houérou, 1993). Multifaceted processes underlying such co-evolution have been observed in the study area over the last decades, leading urban and rural elements to coexist (Moissidis and Duquenne, 1997). In these regards, fallow land is supposed to be a landscape element sensitive to the latent interplay between economy, society and environment. Further investigation is required to ascertain the role of fallow land as (i) a reserve of value for building purposes thanks to real estate speculation, and (ii) as a land stock available for more profitable cultivations, determining agricultural intensification of fringe districts.

Central and local governments are requested to develop land-use plans incorporating measures for stabilization of marginal land, intended as a proxy of sustainable agriculture, natural conservation and preservation of typical cropping systems (Brunori et al., 2016; Giourga and Loumou, 2006; Monarca et al., 2013; Mousazadeh et al., 2009; Portnov and Safriel, 2004; Savo et al., 2014; Colantoni et al., 2013; Monarca et al., 2011; Monarca et al., 2008). Results suggest that direct subsidies to fallow land are a key part of this strategy at least up to 2006. In the last decade, the spatial distribution of land under subsidies was substantially different from the distribution of total fallow land at both local and regional scale. In this renewed context-with the progressive reduction of direct payments to set-aside-subsidies indirectly promoted stability of fallow land only in some areas, e.g., preventing conversion to alternative agricultural use of land in rural marginal areas, while consolidating pressures for land speculation and conversion to urban use in peri-urban districts.

Spatio-temporal trends of total cropland and fallow land-and especially the most recent dynamics under recession-may reflect resilience and adaptability of Mediterranean peri-urban landscapes to changing socio-demographic conditions (Ceccarelli et al., 2014). Under the assumption that soil deterioration and manipulation of rural landscapes result from various kinds of land mismanagement, preserving marginal land from both soil degradation-a particularly acute

environmental process in Southern Europe-and physical loss (e.g., conversion to urban use) is an important issue for any strategy of rural development. In line with a generalized expansion of forests and shrubland and the contemporary loss of farmland in several European regions, promoting the expansion of agroforestry systems with multiple use of the land to develop tourism, wildlife, hunting and sports, is an effective measure contributing to maintain ecological potential and cultural traditions associated with landscapes dominated by fallow land. These opportunities can be combined with extensive grazing and timber production. Based on this framework, territorial variability, topographic complexity and urbanization-driven land fragmentation are a relevant challenge for politicians, policy makers and land managers (Amato et al., 2016; Amato et al., 2018; Aubry et al., 2012; Audsley et al., 2006; Giannakourou, 2005; Kelly et al., 2015; Mosquera-Losada et al., 2012; Paul and Haslam Mckenzie, 2013). Under the assumption that regional transformations impact (positively or negatively) local socioeconomic systems, the resulting environmental conditions required extensive monitoring and coherent policy interventions from a socio-ecological perspective. In this line of thinking, landscape transformations can be more effectively governed by multi-level policies reconnecting short-term and long-term socioeconomic targets, managing together economic downturns and structural change.

4.6. Undermining long-term variations in Mediterranean rural landscapes

Especially in peri-urban areas, land-use changes were promoted by multiple factors revealing controversial aspects at the base of socioeconomic processes (Aguilar, 2008; Briassoulis, 2001; Jomaa et al., 2008; Couch et al., 2007) and leading to new hybrid landscapes, altering the traditional relationship between urban and rural areas (Antrop, 2004). After World War II, a period of intense urbanization began in Europe, with low-quality land, e.g. abandoned fields, pastures, sparse cropland and bare land surrounding large cities, converted to urban use (Carlucci et al., 2017; Di Feliciantonio and Salvati, 2015; Portnov and Safriel, 2004; Zambon et al., 2017). In recent more decades, urbanization has involved an increasing amount of high-quality rural land, with dispersed urbanization having major implications for peri-urban landscape structure, quality and diversity (Weber et al., 2005; Weber and Puissant, 2003; Cakir et al., 2008; Catalàn et al., 2008; Moissidis et al., 1997; Nikolakopoulos et al., 2005).

Driving forces of landscape transformation were deeply investigated in earlier contributions (Burgi et al., 2004; Bürgi et al., 2017; Barbati et al., 2013; Plieninger et al., 2016; Zambon et al., 2018).

Cited article

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Changing traditional rural land-use, cropping systems and agronomic practices towards intensive and specialized food productions and growing livestock along the urban-rural gradient has demonstrated to determine a process of "landscape homologation", owing to the simultaneous action of ecological and socioeconomic factors (Polyzos et al., 2008; Schneider and Woodcock, 2008; Marull et al., 2009; Kizos and Vlahos, 2012; Ribeiro et al., 2016; Santana et al., 2017; Salvati and Sabbi, 2011). In both developed and emerging countries, rural landscapes are increasingly experiencing standardized development models leading to more fragmented and economically-fragile landscape structures, poor ecological quality, increased habitat fragmentation and soil degradation (Ferretti et al., 2014; Frondoni et al., 2011; Sarvestani et al., 2011; Serra et al., 2014; Shrestha et al., 2012), mixing together relict semi-natural areas and scattered low-density settlements in a confused and indistinct matrix (Ferrara et al., 2015; Salvati et al., 2013; Ceccarelli et al., 2014).

Understanding long-term, latent relationships among land-use, socioeconomic constraints and environmental factors is indispensable to clarify the inherent complexity of landscape transformations although, often due to low quality or partial lack of digital data, the influencing drivers remain frequently unknown (Colantoni et al., 2017; Hietel et al., 2005; Marcucci, 2000). Preventing landscape changes toward urbanization under specific socioeconomic dynamics, requires monitoring tools and planning solutions for sustainable development of peri-urban areas (Bruegmann, 2005; Kazemzadeh-Zow et al., 2017; Pili et al., 2017). Developing conceptual and explanatory frameworks founded on empirical case studies is necessary to inform a sustainable land management strategy (Ferrara et al., 2017; Munafò et al., 2013; Colantoni et al., 2016).

Understanding landscape transformations in rural areas may also benefit from a comprehensive analysis of agronomic practices and use of cultivated land in terms of intensification or extensification of cropping systems (Delfanti et al., 2016; Kosmas et al., 2016). In this regard, fallow

land expansion or contraction over time may represent an interesting proxy of different directions and intensity of landscape transformation (Li et al., 2014; Estel et al., 2016; Portmann et al., 2010; Siebert, 2010). Fallow land dynamics may reflect (i) seasonal movements of livestock and mixed farming, (ii) real-estate speculation and (iii) land abandonment (Kizos and Koulouri, 2006; Plieninger, et al., 2011; Van der Sluis et al., 2014).

Fallow land is one of the agricultural soils covers featured by fluctuating and dynamic developments due to exogenous and contextual influences if compared with other uses (e.g. forests) which maintain a more stable and less complex development (Mertens and Lambin, 2000). Spatio-temporal variability in the surface area of fallow may indicate intrinsic environmental factors, hostile agricultural and socioeconomic conditions (Hietel et al., 2005). Comparing metropolitan and rural districts, the present work hypothesized that fluctuations in fallow land surface area are associated with economic cycles, urban-rural relationships, different models of rural development, types and density of cultivation, cropping system (extensive or intensive, with varying degree of mechanization), production inputs and the related agricultural income (Recanatesi et al., 2016). Especially the 2007 crisis in Mediterranean countries has determined socioeconomic conditions leading to a progressive re-colonization of rural land after decades of abandonment or sub-optimal use for cropping. In addition, thanks also to sustainable development issues (Biasi et al., 2015), relevance has been given to the matter of circular economy, outlining the role of fallow land as a stock of land for intensification (or extensivation) of cropping systems at landscape scale (Ferrara et al., 2014; Smiraglia et al., 2015; Tomao et al., 2017).

Based on these premises, the present study investigates agricultural land-use changes in Greece during a long-time span (1970-2015), using spatial analysis, non-parametric correlation and multivariate statistical techniques. The main purpose is to identify (and discuss the role of) on multiple drivers of latent transformation in socioeconomic local systems, based on inherent conflicts with expanding urban regions. The approach proposed in this study was aimed at verifying if landscape composition, structure and diversity significantly changed along the urban gradient during the investigated period. Intuitive and counter-intuitive transformations in the agricultural landscape of Greece included: (i) a spatially-homogeneous and continuous decrease of cropland; (ii) decreasing surface areas (e.g. arable land, horticulture and vineyards); (iii) a parallel growth of tree crops, especially olive; a (iv) spatially-heterogeneous decrease of fallow land concentrated in metropolitan and tourism districts, especially in the last decade characterized by economic crisis; and (v) an increasingly diversified landscape in accessible areas with intermediate population density and close to the sea coast.

4.6.1. Statistical and spatial analysis with landscape diversity indicator

The study area focuses on Greece, a European country with a divided urban system centered on Athens, the capital city, and Salonika (Gemenetzi, 2017). Following Eurostat census, Greek arable land consisted mainly of cereals (29%), where fallow lands are only 4.3%. The latter recorded significant increases (over than 60%) in the last decade (2000-2010), even if the overall agricultural landscape of Greece has extensively altered over time (Van der Sluis et al., 2014). This framework also brings out regional disparities in both socioeconomic and environmental domains, characterizing a thoughtful difficulty to face a shared sustainable development (Cecchini et al., 2018; Tanrivermis, 2003). Innovation in cultivation and mechanization systems have advanced

significantly the agricultural sector since the 1970s. However, several factors (e.g. limited job opportunities in rural areas determining massive emigration towards urban centers) limited the progress of Greek rural society (Kizos and Vlahos, 2012). Furthermore, a limited specialization in high-input agriculture reveals important endogenous and exogenous driving forces, e.g. poorly accessible areas (e.g. islands) and climatic impacts (e.g. droughts) (Kizos and Koulouri, 2006; Kizos and Vlahos, 2012; Grove and Rackham, 2001). In some Greek zones, a gradual decline of practices that combined diverse rural land-uses, e.g. fallow lands, were used as olives and grazelands for the growing livestock, decreasing land-use diversity (Van der Sluis et al., 2014). The simplification of local multifunctional land-use systems to intensive livestock grazing changed ecosystem equilibrium towards environmental, soil, vegetation and biodiversity degradation processes (Bakker et al., 2005; Iosifides and Politidis, 2005; Kizos et al., 2005; Mancino et al., 2016; Zalidis et al., 2002; Plieninger et al., 2010). In fact, Greece is one of the European countries suffering from soil erosion and desertification, loss of organic matter, salinization and soil compaction (Kairis et al., 2013; Karamesouti et al., 2015; Pisinaras et al., 2010), with about 20% of its land surface subject to erosion risk (Barbayiannis et al., 2011; Kosmas et al., 2006).

Agriculture play an important factor role in the local economy in the Peloponnese peninsula, while industry has developed in the northern region, such as Central Macedonia (Ragkos et al., 2015) and close to the metropolitan area of Athens. Whereas on the eastern plain, Thessaly is notable by its intensive agriculture and manufacturing (although declined in the 1980-1990s). As one of the Mediterranean Islands, Crete has established an economy based mainly on agriculture and tourism (Ioannides et al., 2001).

In the present study, provinces were defined as the elementary spatial unit since administrative boundaries have been largely used in both quantitative exercises and qualitative case studies dealing with urban geography and landscape analysis (Salvati et al., 2013; Munafò et al., 2013). Based on the spatial distribution of 5 basic agricultural land-use classes (arable land, garden crop, vineyards, tree crop and fallow land) at 6 years (1970, 1979, 1988, 1997, 2006 and 2015) derived from Agriculture statistics of Greece at prefectural level, a quantitative analysis based on correlation and multivariate techniques was proposed to recognize recent agricultural changes in the Greek landscape. From this set of variables, useful indicators were provided to understand changes in agricultural landscapes in Greece (Cecchini et al., 2018). Percent share of land by each land-use class and, specially, percent share of fallow land in total agricultural land in Greece were depicted on map by the ArcGIS software (ESRI Inc., Redwoods, USA) using the province's boundaries as spatial unit. Fallow farmland has been already used as consistent indicator in numerous investigations works to assess rural changes (Castro et al., 2016; Levers et al., 2015; Estel et al., 2015). The term 'fallow' defines agronomic practices aimed at securing sustainability of cropping systems leaving land uncultivated for one (or more) annual cycle(s). Fallow systems are traditional management practices aimed at reestablishing soil fertility, protecting rural areas from aridity, low soil fertility and productivity, reducing risk of erosion (Castro et al., 2016; Boellstorff and Benito, 2005). Establishing provisional patches, fallow land compensates habitat loss and mitigate persistent effects of agricultural intensification (Huusela-Veistola et al., 2011). Fallow lands are traditionally involved in agronomic schemes based on the principle of crop rotation (Boellstorff and Benito, 2005), getting nutrient for the forthcoming cropping season (Robleño et al., 2017).

A summary analysis of agricultural land-use change in Greece was developed using a Principal Components Analysis (PCA). The latter was performed on the data matrix composed by 51 provinces and the percent land surface classified at 5 basic agricultural land-use classes in the investigated years. As the PCA was based on the correlation matrix, the number of significant factors was chosen by retaining the components with eigenvalue > 1. Based on the scores of the most important factors, provinces were reported and thus mapped into different groups. Entities (agricultural land-use classes and provinces) are placed close each other in the factorial plane indicate spatial relation; while then they oppose each other, they indicate spatial segregation (Salvati et al., 2008).

Focusing on agricultural land-use change and relative landscape diversification during the investigated temporal period, the relationship among contextual variables and agricultural land-use in Greece was explored using non-parametric pair-wise Spearman rank correlation analysis testing for significant correlations at $p < 0.05$ after Bonferroni's correction for multiple comparisons. The contextual variables describe: (i) per-capita income; (ii) population density; (iii) distance from Athens; (iv) distance from Salonika; (v) distance from the sea coast; and (vi) tourism district. The percent share of garden crop in total agricultural area and the two dummies (presence of an international airport and of a public university) were not correlated significantly with any other variable.

A Spearman rank correlation was also applied between Pielou J evenness index of landscape diversification and selected context variables during the studied period (1970-2015), illustrating agricultural landscape diversification in Greece (Schaich et al., 2015). Pielou's index defines the evenness degree of landscape diversification. It was used in this work to observe the directions of distinct indicators, defining the stability of agricultural systems during a long-time span (1970-2015). The value of a diversity index increases both when the number of types increases and when evenness increases. For a given number of types, the value of a diversity index is maximized when all types are equally abundant. Derived from the Shannon index, Pielou's index was applied to the composition of the landscape found in each province according to the following formula:

$$J = H'/H_{max}$$

where H_{max} is the natural logarithm of the number of considered classes (n = 7). Although Shannon index ranges from 0 (low diversity) to infinity (high diversity), Pielou's index ranges between 0 (low evenness) and 1 (high evenness).

4.6.2. Rural changes in Greece (1970 - 2015)

The predominant agricultural land-use class in Greece can be associated with crops on arable land, recording the highest scores (> 50%) in the whole study period, 1970-2015 (Table 4.16). However, percent share of land by land-use class pointed out relevant changes for the Greek agriculture. The understanding of the agricultural variations is tangible, especially for arable land. Even though the latter cover the largest agricultural area in Greece, arable land reduced their surface area from 1979 (61.9%) to 2015 (52.9%). The other agricultural areas took on different trends. Viniculture has also decreased its surface rate over time but in a more contained way (from 5.4 in 1979 to 2.9% in 2015). Even fallow land recorded a decreasing rate. Gardens have undergone a slight increase over time, however, in the last year of survey (2015) their percent share of land reduced.

Areas under trees (e.g. compact plantations, including olive trees) are the only ones that continuously increase their surface area over time (from 16.6% in 1979 to 31.0% in 2015).

Table 4.16. Agricultural changes in Greece, 1970-2015 (percent share of land by land-use class).

Year	Crops on arable land	Garden area	Vines (grapes and raisins)	Areas under trees (compact plantations)	Fallow land
1970	61.9	2.6	5.4	16.6	13.4
1979	60.0	2.8	4.8	19.6	12.8
1988	59.0	2.8	4.1	22.3	11.8
1997	57.6	3.1	3.4	24.4	11.5
2006	55.3	3.0	3.4	26.9	11.4
2015	52.9	2.1	2.9	31.0	11.2

Spatial dynamics occurred in the last 45 years are expressed with the percent share of fallow land in total agricultural land in Greece (Figure 4.25). The highest percentages (>20%) are evident in specific provincial agricultural models linked to intensive agriculture and crop rotation. From the first exploratory analysis, data revealed that since 1970-79, especially in Attica and Peloponnese, fallow land was more concentrated. In the central northern area, fallow land areas exposed a more homogeneous distribution, associated to the most intensive cultivation models (e.g. horticultural crops) and viticulture. However, an increased incidence of fallow land has occurred in recent years in this area, especially around Thessaloniki. In the southern part of Greece, fallow land has also seen an intense decline since 1988, conducing to a sharp reduction in its area in the following years and thus reaching scores less than 10%. The Cyclades Islands recently (in 2015) demonstrated a clear abandonment of agricultural systems, together with the Corinth area.

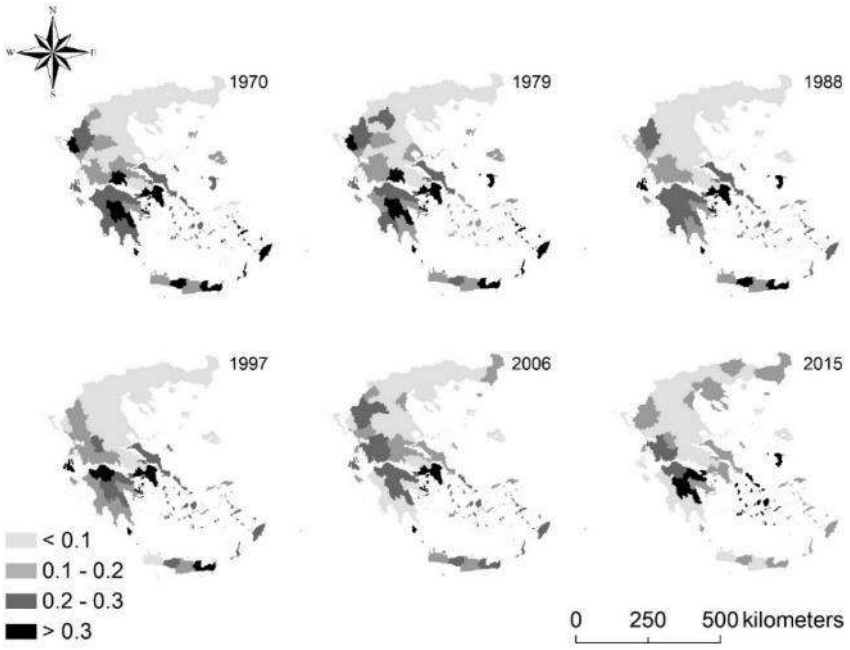


Figure 4.25. Percent share of fallow land in total agricultural land in Greece, 1970-2015.

The PCA extracted three factors with cumulated variance of about 85% (Table 4.17). The most important factor (explaining 47.2% of total variance) defined the Greek provinces which base their economic production on tree crops (and wine-growing system from 1979 to 1997), opposing to arable areas. The different cultivation system emerges by highlighting high density and intensification

crops (e.g. olive trees) and viniculture, which can be traced back to extensive systems. Wine-growing system contrasts with other crops e.g. arable areas. PC1 was positively linked to fallow land until 1997, as well as to largely extensive cultivation systems. Fallow land can be linked to a precise landscape, indicating underused land in extensive economic cultivation systems with more heterogeneous areas. While, in strong systems (e.g. horticultural and arable systems), potential fallow land is constantly exploited.

Table 4.17. Loadings (> |0.6|) of PCA on agricultural land-use change in Greece.

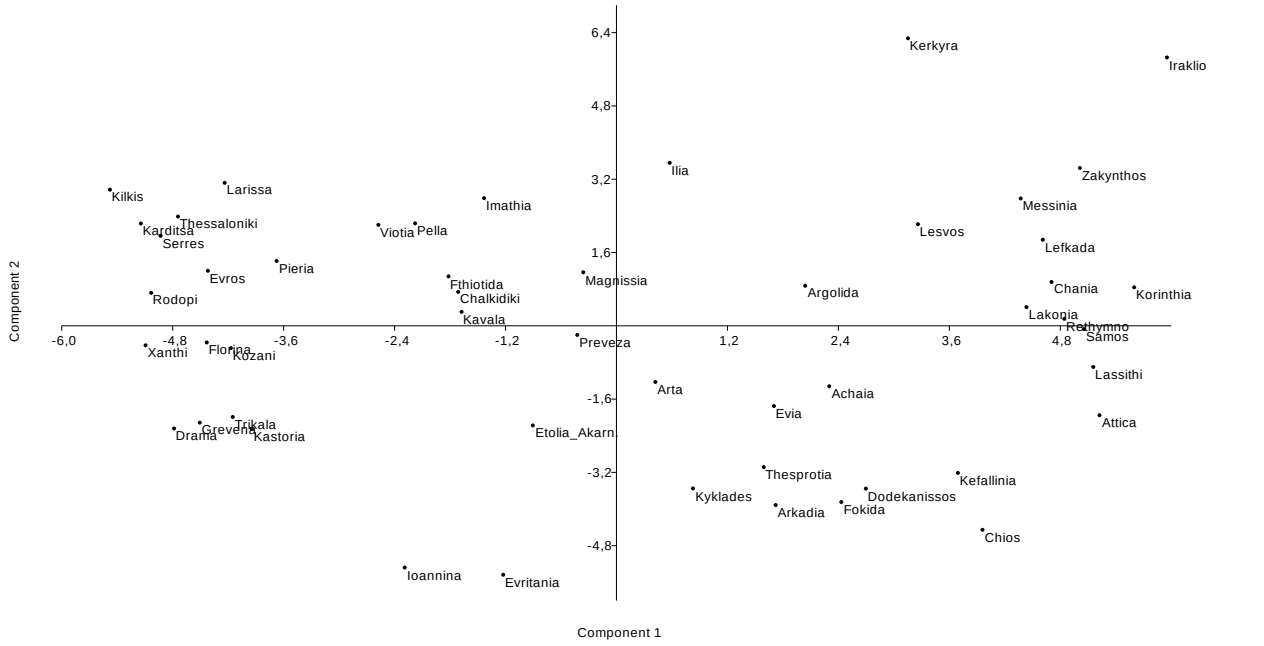
Variable	PC1	PC2	PC3	Variable	PC1	PC2	PC3
Ara70	-0.98			Tre70	0.80		
Ara79	-0.98			Tre79	0.84		
Ara88	-0.99			Tre88	0.85		
Ara97	-0.99			Tre97	0.86		
Ara06	-0.98			Tre06	0.85		
Ara15	-0.95			Tre15	0.85		
Cro70		0.95		Vin70			
Cro79		0.95		Vin79	0.67		0.63
Cro88		0.96		Vin88	0.68		0.64
Cro97		0.95		Vin97	0.63		0.69
Cro06		0.96		Vin06			0.71
Cro15		0.85		Vin15			0.71
Fal70	0.64						
Fal79	0.66						
Fal88	0.72						
Fal97	0.68						
Fal06		0.62					
Fal15		0.61					
Expl. Var. %	*47.2*	*24.1*	*13.4*				

The second component (explaining 24.1% of total variance) revealed contexts with a strong agricultural vocation dedicated to crop lands. For PC2, fallow areas are positively correlated in recent years (2006-2015). They are linked to specific rural areas at the provincial level. With a relevant presence of crop areas, a greater number of fallow lands were also examined, highlighting extensive cultivation system. Agrarian provinces resulted more likely to occupy fallow lands (soil at rest or abandoned), especially where there is more land available for crops use; on the other hand, in the provinces where there is a more intensive cultivation system and less land availability, the fallow land is smaller. Component 3 (explaining 13.4% of total variance) demonstrated definite provinces with a wine specialization, also correlated to external factors (e.g. territorial, geographical and socioeconomic issue).

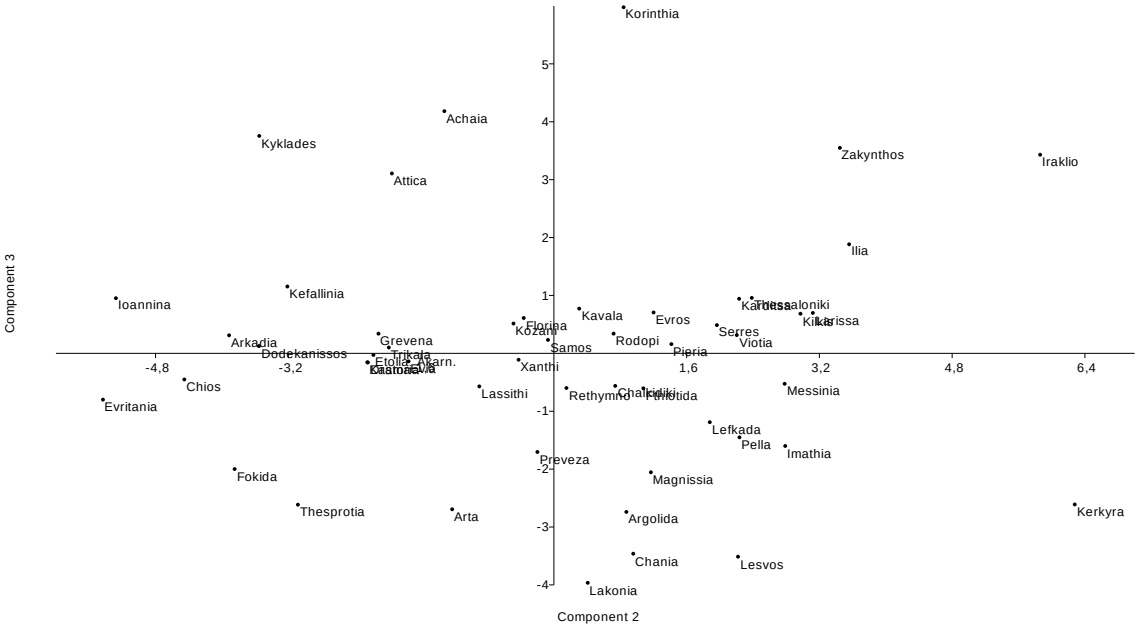
Scores of first principal components on agricultural land-use change in Greece are exposed in Figure 4.26. The first quadrant identifies the agricultural areas designed for vinicultures and olive trees, e.g. Kerkyira and Zakynthos. Their extensive landscape appeared fragmented, diversified and heterogeneous, offering medium-low income. These agricultural systems with a high agricultural vocation exposed limited fallow land. In the fourth quadrant, the provinces identified expressed a strong extension of fallow land, identifying as reservoirs for pastoralism; while, they own a lower percentage of total agricultural land. This limited agricultural vocation derived from other factors, such as poorly accessible areas (e.g. islands) and climatic influences (strong aridity, such as in Chios).

In the fourth quadrant, there are also areas with little agricultural vocation, such as urban areas (e.g. Attica, Dodecanese and Achaia).

The contexts on the left side of Figure 4.26 highlighted provinces with annual and arboreal crops, distinguishing the most intensive systems (second quadrant) as in northeast Greece (e.g. Larissa and Thessaloniki), from less intensive ones (third quadrant) recognizing more disadvantaged and less accessible contexts towards the Ionic Sea (e.g. Evritania and Ioannina). The latter areas are located far from the coast, revealing a widespread traditional agricultural system dominated by less intensive annual cultivation than other areas.



(a)



(b)

Figure 4.26. Scores of principal components on agricultural land-use change in Greece (a) PC1 vs PC2, (b) PC2 vs PC3.

The scores of the first three principal components on agricultural land-use change in Greece are exposed in maps (Figure 4.27). Axis 1 outlines the latitudinal gradient, dividing Greece into northern and southern areas. The arboreal agrarian systems are placed in the north, while in the south the arboreal areas are establish. In addition, the territorial structure emerges. In the north, total land-use is homogenously distributed, while, a fragmented and heterogeneous landscape defines a greater diversification and biodiversity in the south. However, systems in the south are less stable, not guaranteeing high incomes. Furthermore, PC1 proved a territorial structure that is composed of different degree of soil fertility and climatic conditions. In fact, the yield of tree crops, such as olive trees, are not adapted to intense arid environments; for this reason, tree crops appeared to be more productive in the northern areas. Axis 2 instead divides Greece into eastern and western areas. Towards the Aegean Sea, areas express a strong agricultural vocation, defining an ease accessibility. While, the western contexts exhibited less agricultural vocation and territorial accessibility, typical of the Ionian zones.

Axis 3 expressed an evident urban-rural gradient. Urban and compact areas diverged to more rural provinces since they are more accessible and connected by an infrastructure network. In this group, Athens and its region (Attica) emerged with Crete, Macedonia and Thessaloniki, followed by medium-density urban settlements, e.g. Larissa, Volos and Ioannina; finally, the most rural areas can be noticed because they are less accessible and more marginal, such as Achaia.

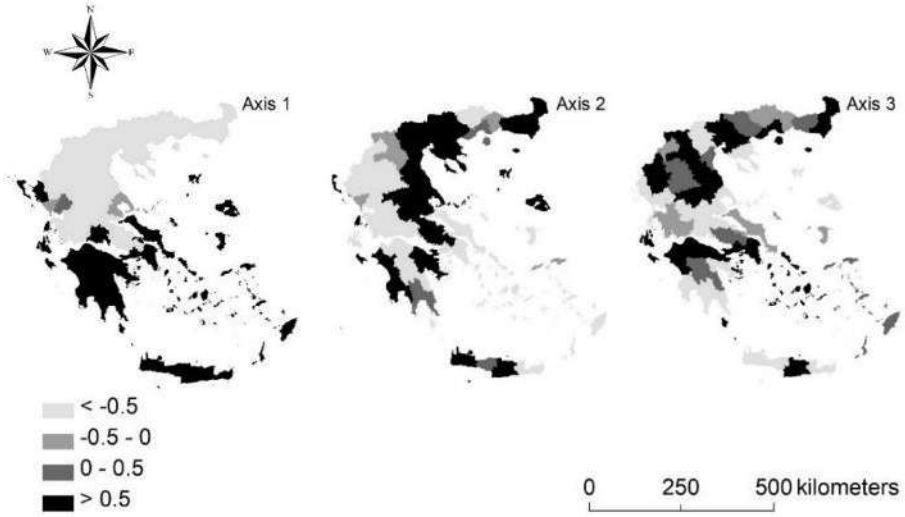


Figure 4.27. Scores of the selected components on agricultural land-use change in Greece (a) PC1, (b) PC2, (c) PC3.

Pair-wise Spearman rank correlation analysis between contextual variables and agricultural land-use was applied to explore spatial changes in Greece during the investigated temporal period (1970-2015) (Table 4.18). The variables express: (i) per-capita income; (ii) population density; (iii) distance from Athens; (iv) distance from Salonika; (v) distance from the sea coast; and (vi) tourism district.

Table 4.18. Spearman rank correlation between context variables and agricultural land-use in Greece, 1970-2015*.

Variable	Per-capita income	Population density	Distance from Athens	Distance from Salonika	Distance from the sea coast	Tourism district
Arable70	-0.54			-0.84	-0.54	-0.60
Arable79	-0.52			-0.80	-0.52	-0.59
Arable88	-0.48			-0.81	-0.54	-0.60
Arable97	-0.45			-0.79	-0.56	-0.57
Arable06				-0.79	-0.54	-0.58
Arable15				-0.79	-0.51	-0.57
Crops70		0.52				
Crops79		0.50				
Crops88		0.51				
Crops97		0.50				
Crops06		0.50				
Crops15						
Fallow70				0.74		
Fallow79				0.69		
Fallow88			-0.46	0.77		
Fallow97			-0.47	0.72	0.46	
Fallow06				0.53		
Fallow15						
Trees70				0.61	0.54	0.64
Trees79				0.64	0.53	0.60
Trees88				0.63	0.51	0.55
Trees97				0.62	0.51	0.53
Trees06				0.65	0.54	0.53
Trees15	0.58			0.54		
Vines70	0.62			0.60		0.44
Vines79	0.61			0.59		0.51
Vines88	0.61			0.59		0.49
Vines97	0.62			0.59		0.49
Vines06	0.63			0.56		0.49
Vines15				0.63	0.49	0.51

* Percent share of garden crop in total agricultural area, and the two dummies "presence of an international airport" and "presence of a public university" were not correlated significantly with any other variable (significance tested at $p < 0.05$ after Bonferroni's correction for multiple comparisons).

Beginning with the variable per capita income, rich regions are particularly dedicated to viticulture, resulting in high income in the primary sector and opposing to arable land. These contexts coincide with industrial regions, located in the central and northern part of Greece, owning a more intensive agricultural system.

Agricultural areas pointed out a higher population density linked to crops land. In fact, rural areas in Greece are defined by a settlement model with a medium population density. In 2015, this complex system decreased along the rural-urban gradient. With a greater mixed gradient, a polycentric system can be observed in which agriculture also became part of the urban context, highlighting medium-high population density.

Three distances were calculated to better understand the relationship between urban and rural contexts. The first variable corresponded to the distance from Athens, the capital of Greece. Fallow (and abandoned) areas grew near the compact core of Athens. This revealed a geographical factor, which can only be perceived in 1988 and 1997, where the resting agricultural systems were situated in compact urban areas, perhaps waiting for speculative activities to perform urbanization

processes. The second distance variable calculated the distance from Thessaloniki, the Greece's co-capital city. Topographical and landscape factors expressed a greater rural vocation. In fact, the neighboring region of Macedonia is characterized by a strong presence of arable land. Fallow land (coinciding with abandoned and unused land), tree and wine-growing areas are located far to Thessaloniki. The third distance variable defined the distance from coastal areas. With greater distances, there was a larger incidence of trees, particularly olive trees; however, the presence of areas destined to vineyards coincided at a greater sea distance from the sea coast in 2015. The arable lands are located close to the sea coast. Finally, the outcomes concerning the tourist districts followed similar trends to those from the distance from the coast. In fact, a greater presence of trees, such as olive groves and vineyards, were situated far from tourist centers; while, arable land were located near tourist centers during the entire length of time threshold assumed.

Using the previous variables and parameters, another Spearman rank correlation were applied among Pielou J evenness index of landscape diversification and contextual variables in Greece (Table 4.19). Correlation has assumed an overall decreased. However, agricultural landscapes are different depending on the existing crop. Rural landscapes resulted to be less varied with arable land (from -0.91 in 1979 to -0.67 in 2015). While, they are more diversified if they are dedicated to vineyards, fallow land and arboreal systems (scores higher than 0.50). Heterogenous landscapes were associated with per-capita income, where extensive agricultural landscapes are more diversified and devoted to other land-uses. Finally, diverse landscapes can be detected in the urban core of Athens and along coastal areas; while, the most homogeneous landscapes are located near Thessaloniki. The spatial distribution of J indexes was illustrated in Figure 4.28, confirming the findings presented above. Landscape diversification recently increased in the northern part of Greece, although it is possible to detect a stable landscape homogeneity over time. The most heterogenous areas coincide with Peloponnese, Attica and Crete. Especially in Crete, its intensive agricultural systems in the recent period stimulated urbanization processes, linked to the tourism sector and thus leading to a contraction of agricultural landscapes.

Table 4.19. Spearman rank correlation between Pielou J evenness index of landscape diversification and selected context variables in Greece, 1970-2015*.

Variable	1970	1979	1988	1997	2006	2015
Arable land	-0.91	-0.87	-0.84	-0.82	-0.67	
Vineyards	0.69	0.68	0.68	0.72	0.63	0.49
Tree crop	0.74	0.70	0.68	0.67	0.51	
Fallow land	0.79	0.81	0.84	0.79	0.66	0.55
Income per-capita	0.56	0.58	0.53	0.53	0.48	
Distance from Athens	-0.40	-0.46	-0.49	-0.49	-0.46	-0.50
Distance from Salonika	0.82	0.77	0.74	0.74	0.61	
Distance from the sea coast	0.55	0.54	0.54	0.54	0.48	
Tourism district	0.53	0.48	0.45	0.45		

* Percent share of garden crop in total agricultural area, population density and the two dummies "presence of an international airport" and "presence of a public university" were not correlated significantly with Pielou evenness J index at every year of investigation (significance tested at $p < 0.05$ after Bonferroni's correction for multiple comparisons).

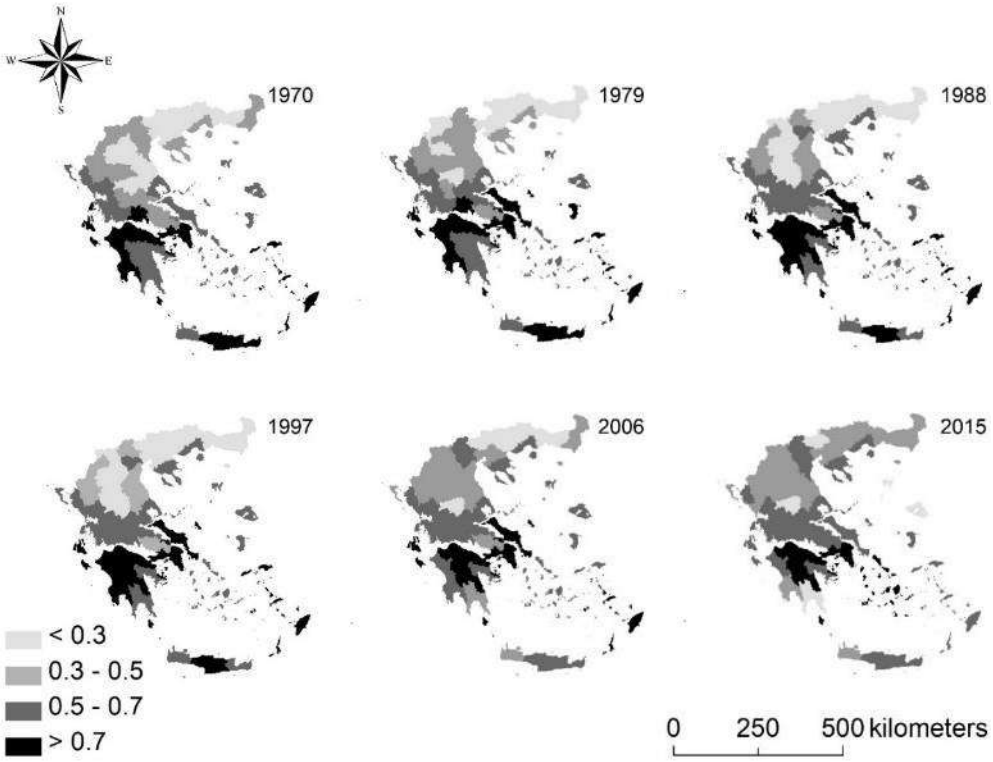


Figure 4.28. Spatial distribution of Pielou J evenness index illustrating agricultural landscape diversification in Greece, 1970-2015.

4.6.3. Agricultural land-use, fallow land and landscape diversification

Fallow land assumes the role of land stock for different functions: (i) crop rotation, seasonal movements and mixed farming (Grove and Rackham, 2001; Boellstorff and Benito, 2005); (ii) more intensive crops for farming systems where fallow land can be considered as set-aside area (Boellstorff and Benito, 2005; Tscharntke et al., 2011); (iii) pastoral purposes, fertilizing land and mitigate pervasive effects of agricultural intensification (Huusela-Veistola et al., 2011; Robleño et al., 2017); and (iii) abandonment of agricultural land even designated for urban and touristic purposes (Salvati, 2013; Salvati, 2016; Tzanopoulos et al., 2007). Fallow lands can positively impact on biodiversity and agro-ecosystem, allowing a multifunctional land-use and income diversification (Castro et al. 2016). Thanks to this investigation, findings underlined that, where fallow land is less present, there are wrecks and critically connected agricultural systems; while, with more land available for production, a greater rural intensification can be conducted to a greater fallow land. Furthermore, fallow land can indicate soil fluctuations that are not closely linked to agricultural use. For instance, greater fallow land near Athens can reveal an abandonment of agricultural land for speculative purposes. Specially, outcomes revealed that since 1970-79, especially in Attica and Peloponnese, fallow land was more concentrated. In the central northern area, fallow land areas exhibited a more homogeneous distribution, associated to the most intensive cultivation models (e.g. horticultural crops) and viticulture, which is an important source of income for farmers (Ragkos et al., 2015; Ioannides et al., 2001; Castro et al., 2016). In fact, Mediterranean olive plantations and vineyards were not abandoned since they guarantee profitable products of high value while arable cultivations were progressively abandoned for the easy-to-cultivate lowlands (Kizos et al., 2010). For instance, an increased incidence of fallow land has occurred in recent years in the northern area, especially around Thessaloniki. While, fallow land recorded an intense decline in the southern part

of Greece since 1988, conducing to a sharp reduction in its area in the following years and thus reaching scores less than 10%. Among the Greek islands (Ioannides et al., 2001), the Cyclades demonstrated an intensive abandonment of agricultural systems in 2015, probably for tourist settlements, together with the Corinth area. In the latter circumstance, it can be associated with recent speculation actions towards the construction of the high-speed railroad that link Athens to Corinth (Rontos et al., 2016). In this regard, fallow land can also be defined as land reservoir awaiting both cultivation and speculative actions linked to urbanization and infrastructure developments (Salvati, 2013; Salvati, 2016).

The analysis revealed some inherent particularities of all Greek rural areas. Despite a total reduction in agricultural land, there is a growth in forests, which may have a mixed vocation (both intensive and extensive). For instance, Greece is one of the main producers of pistachios in Europe (Komnitsas and Doula, 2017), mainly in marginal and remote areas, such as in in Aegina where pistachio plants area visible crop producing income with limited production (Bartzas and Komnitsas, 2017). In addition, an increasing wine specialization emerged in Greece as monoculture, due to the connected exogenous factors (e.g. territorial, geographical and socio-economic) enabling profitable income.

From the findings obtained, the variables diverged from 2006 to 2015. This can be justified by the CAP incidence and its agricultural subsidies. From 1970 to 1997, the CAP-driven subsidy regime ensured the stability of agricultural systems in Europe (including Greece) (Kizos et al., 2012). However, since the 1990s and mostly evident in recent years, the support offered by CAP has decreased, leading to real changes in the agricultural sector. Correspondingly, the Greek agricultural system has undergone effective structural and functional changes in recent years, leading to significant transformations, which can also be seen along its agricultural landscapes (Kizos et al., 2010). In addition, the agro-environmental EU regulation (e.g. 2078, 2079) has allowed the awareness of a more conservative and extensive agriculture, with less arable land and more devoted to viticulture and olive growing. In the 2000s, the reduction in CAP subsidies triggered an agricultural restructuring, where geography and landscape in Greece became less stable and heterogeneous. Such dynamics that affect the agricultural land-use, especially fallow land, define comprehensible changes at different geographical scales (Serra et al., 2017; Duvernoy et al., 2018; Perrin et al., 2018).

In addition to EU subsidies, the 2007 economic crisis has taken on a decisive and impacting role in Greece (Salvati, 2016), accelerating land-use changes in its primary sector which can be spatially noticeable. The richest and industrial regions located in central and northern Greece, with more intensive agricultural systems, have particularly devoted to viticulture than to arable land over time, resulting in higher income for their farmers. Nevertheless, other crops (e.g. olive trees) are not present due to their severe temperatures of the northern area that make these environments unattractive for some Mediterranean crops. The diversification has recently increased in the north, although a stable and homogeneous landscape can be perceived over time (Ragkos et al., 2015). The most heterogeneous areas are those of Peloponnese, Attica and Crete. In Attica region, peri-urban areas are composed by urban and rural elements preserving a great percentage of olive groves, portraying mixed (and probably high-quality) landscapes (Moissidis and Duquenne, 1997). In fact, results demarked that olive landscapes record a strong rural diversification, also correlated to their strong inclination to rapid changes. For instance, in the last period, the intensive agricultural systems have stimulated urbanization processes, e.g. linked to the tourism sector in Crete, leading to a

contraction of agricultural landscapes. Thus, in recent years there has been less diversification in this case.

In summary, transformations of agricultural land-uses can be related to fallow land changes, which reveal multiple drivers: (i) geographical factors (north-south, east-west, urban-rural) correlating to climatic conditions, distance factor and accessibility of rural contexts; (ii) CAP incidence and its agricultural subsidies (Tzanopoulos et al., 2007; Vogiatzakis et al., 2008); (iii) socioeconomic transformation, as an exogenous variable linked to the increase in income; (iv) industrial production shift and greater presence of service activities, especially in the northern area of Greece and in the urban area of Athens where there is a greater specialization in agro-industrial and monocultural practices (Ragkos et al., 2015) or tourism (Ioannides et al., 2001).

Evaluating the possible effects of different land-use alternatives on biodiversity is essential for guiding objective management choices (Cardador et al., 2014; Colantoni et al., 2015; Zitti et al., 2015). The present study discovered landscape change paths in Greece and their possible impact on landscape diversity using spatial analysis and multivariate statistical models. Results pointed out the usefulness of comparative and multi-temporal approaches to landscape changes in complex regions (Alphan, 2003; Marull and Mallarach, 2005; Paul and Tonts, 2005; Detsis et al., 2010; Cuadrado-Ciuraneta et al., 2017).

Discriminating the future of agricultural landscapes in Greece is hard due to the different driving forces that are involved and vary intensity (Kizos and Vlahos, 2012). Results designate the protection of a spatially balanced landscape diversity structure along the urban-rural gradient as a key target for strategies increasing sustainability in the Mediterranean regions. The future objectives must require appropriate policies and strategies for sustainable land management, avoiding (i) speculative actions linked to urbanization processes, (ii) ineffective environmental policies on quality and diversity of peri-urban landscapes, (iii) soil sealing and degradation (Couch et al., 2007).

A shift from a spatially-balanced, structurally-complex and functionally-diversified agricultural landscape to more homogeneous systems defines a typical process of simplification and homologation typical of contemporary rural regions and reflecting a progressive decline in land-use diversification, that impacts ecosystem functioning and increase ecological fragility of relict cropping systems (Sallustio et al., 2018). Using multi-temporal land-use statistics and high-resolution diachronic maps, further studies are essential to investigate the role of structural and functional transformations in rural landscapes as a response to increasing anthropogenic pressure and climate change impacts along urban-rural gradients (Serra et al., 2014). In this regard, analyzing the changing spatial configuration of landscapes, may provide a knowledge base supporting a sustainable management of traditional cropping systems aimed at reducing land abandonment and soil misuse, mixing together operational indications from geographical, socioeconomic and ecological perspectives (Kasanko et al., 2006; Biasi et al., 2017; Feranec et al., 2010). Integrating agricultural statistics, land-use variables and landscape diversity indexes with socioeconomic indicators describing local contexts may provide a suitable tool for a comprehensive assessment of landscape transformations contrasting economically-dynamic and more remote regions.

4.7. In-between sprawl and neo-rurality

During the last half century, urban sprawl has progressively transformed metropolitan regions into well-connected and low-density residential areas (Cecchini et al., 2018; Colantoni et al., 2016; Salvati, 2014; Salvati, 2016; Salvati and Ferrara, 2013; Salvati et al., 2013; Zambon et al., 2017). This recent kind of urbanization has intensively changed the traditional rural landscape, leading to a new definition of 'rurality' (Cecchini et al., 2018; Duvernoy et al., 2018; Ferrara et al., 2015; Gkartzios et al., 2017; Gospodini, 2006; Kizos and Vakoufaris, 2011; Kristensen et al., 2001; Makhzoumi, 1997; Sabbi and Salvati, 2015; Salvati and Ferrara, 2014; Salvati et al., 2017; Serra et al., 2008). Transformation of agricultural landscapes-and particularly farmland abandonment-are widespread land-use changes in many European regions, due to increasing yields on productive land, conservation policies and the increasing import of agricultural products from other regions (Colantoni et al., 2015; Estel et al., 2015; Kizos, 2010; Kizos et al., 2011; Zambon et al., 2018). Among the most relevant consequences, land consumption due to residential development and economic growth became one of the most thoughtful environmental pressures on landscapes, especially in metropolitan areas (Baró et al., 2016; Ceccarelli et al., 2014; Salvati et al., 2015).

Cited article

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A sustainable land management strategy for metropolitan regions is increasingly required to quantify long-term and short-term land-use changes, recognizing trends in their main drivers (Colantoni et al., 2015; Colantoni et al., 2016; Colantoni et al., 2017; Tanrivermis, 2003; Zambon et al., 2017). Because of multifaceted social processes, land-use changes involve multiple interacting actors (Garcia Latorre et al., 2001). Since the early 1980s, Mediterranean cities have experienced a rapid transition from mostly compact and dense settlement models to various steps of a more discontinuous morphology characterized by huge expansion around inner cities (Schneider and Woodcock, 2008). Trends toward 'compact growth' observed up to the early 1990s and the following 'discontinuous urbanization' have affected land-use structure and peri-urban farming in a different way (Salvati et al., 2015; Colantoni et al., 2016; Salvati et al., 2015). How the changing land-use represents a target for policies mitigating soil consumption and promoting peri-urban agriculture in Mediterranean fringes has been discussed (Salvati, 2013; Pereira et al., 2017; Salvati et al., 2011; Mavrakis et al., 2014; Zambon et al., 2018), although empirical evidence from different socioeconomic contexts is still required. With the final objective to define a new concept of 'rurality' for territorial contexts characterized by dispersed urban settlements (e.g., urban sprawl), indicator-based quantitative approaches are essential for understanding local transformations which alter the traditional urban-rural gradient typical of mono-centric cities in the Mediterranean region, allowing identification of new central and peripheral places, and the respective changes over time (Colantoni et al., 2017; Parr, 2014; Salvati and Serra, 2016).

Based on these premises, the present study focuses on a Southern European case study (Athens, Greece) investigating the latent relationship between sparse (rural) settlements and the evolution of the respective socio-demographic local context. Athens can be considered a Mediterranean compact city (Arapoglou and Sayas, 2009; Di Feliciantonio and Salvati, 2015; Maloutas, 2004), where a long-

term urban development occurred alternating settlement densification and dispersion in a framework of planning deregulation (Carlucci et al., 2017; Chorianopoulos et al., 2010; Chorianopoulos et al., 2014; Gkartzios, 2013; Rontos et al., 2016; Souliotis, 2013; Zitti et al., 2015; Ferrara et al., 2017). However, the most recent expansion was the result of relatively strict planning regulations that were relaxed with the aim to facilitate and speed up the construction of Olympic infrastructures, (urban and peri-urban) road and railways networks and the new international airport. At the same time, the recent Athens expansion provides a peculiar contribution to Mediterranean urban history; according to Di Feliciantonio and Salvati (Di Feliciantonio and Salvati, 2015), "urban diffusion processes vary widely according to the context, as does the socio-economic profile of the actors, stressing the need to think about different 'southern European alternatives' of sprawl. (…) In the case of Athens, the main actors of urban diffusion appear to be medium-upper class, white-collar households", suggesting the inherent complexity and specificity of the case study.

By considering together territorial and socioeconomic transformations, settlement expansion and infrastructural development in a metropolitan system moving from economic expansion to crisis (Rontos et al., 2017), the present work focuses on the intrinsic relation between sprawl and new spatial configurations of rural landscapes, possibly reflecting a new concept of 'rurality' in Mediterranean Europe. With economic crisis, workers have experienced falling incomes and contraction of public services; unemployment and urban poverty have alimented the so-called 'back to the land' movements, reconstructing the condition for a 'new rurality' (Gkartzios and Remoundou, 2018). A spatially-explicit investigation of local-scale dynamics of population living in sparse settlements over different phases of urban growth and rural development (1961-2011) contributes to exploring such changes in a region more recently undergoing recession and experiencing austerity urbanism, such as Attica (Greece). Under the assumption that rural mobility is often linked to urban processes (Gkartzios and Remoundou, 2018; Bell and Osti, 2010; Stockdale, 2016), the adopted approach aims at providing a comprehensive outline of the rapidly-evolving socioeconomic conditions in Athens, the capital of Greece, over different time intervals in recent urban history (Milbourne, 2007). Based on the results of this study, notions such as 'rurality' and 'rural development' can be discussed within a new framework considering together urban sprawl, counter-urbanization and rural migration processes (Benson and O'reilly, 2009); in this regard, residential mobility is intimately related with specific socioeconomic attributes in turn shaping counter-urbanization, increasingly seen as an ideological and political issue (Gkartzios and Scott, 2015; Murdoch et al., 2003; Gkartzios and Scott, 2014).

4.7.1. Examination of sparse settlements in Attica

The investigated area includes the Athens metropolitan region administered by the regional authority of Attica (Greece). Although specialized in Mediterranean dry crop systems (olive trees and vineyards), the area underwent rapid and continuous urban growth over the last two centuries (Gargiulo Morelli et al., 2014; Kallis, 2010).

Statistical data aggregated at the municipal scale and derived from the General Censuses of Population and Households held every 10 years between 1951 and 2011 by Hellenic Statistical Authority (hereafter ELSTAT) were considered when designing indicators that assess size and extent of sparse settlements at an enough detailed geographical scale. Municipalities were selected as the elementary analysis unit for a spatially-explicit investigation of local-scale dynamics of

population living in sparse settlements over a long-term period encompassing different phases of urban growth and rural development in Attica. For each municipality, census data allowed quantification of population (i) residing in central settlements (the compact center giving the name to each municipality) and (ii) living in sparse settlements; these settlements are physically separated from the core settlements and are scattered across the municipal territory. A specific indicator estimating the size of sparse population at each census date was calculated as the percent share of population living in sparse settlements in total population residing in each municipality. This indicator may outline the spatial characteristics of farming systems and the related pattern of population distribution. In contexts with traditional rural areas, sparse settlements may host a relatively large population in respect with the corresponding center. With important transformations in rural districts (e.g., urban expansion), population living in sparse settlements may decrease, leading to more polarized settlements, e.g., separating high-density locations from (totally or partially) abandoned areas which are no longer cultivated (Kristensen et al., 2001; Serra et al., 2008; Zambon et al., 2018; Salvati et al., 2015).

Additional indicators were considered here with the aim to assess the basic characteristics of the socio-demographic local contexts between 1961 and 2011. A coherent and homogeneous set of contextual indicators was unavailable for the first decade of study (the early 1950s). Indicators were calculated from official datasets based on ELSTAT censuses and public registers or other national/international statistical sources and include: (i) average farm size (hereafter 'Afs'), (ii) population growth rate (% per year, 'g'), (iii) forest land in total landscape (%, 'f'), (iv) protected areas ('p'), (v) residential buildings in total building stock (%, 'r'), (vi) industrial buildings in total building stock (%, 'i'), (vii) buildings with tourism use in total building stock (%, 't'), (viii) commerce/service buildings in total building stock (%, 'e'), (ix) multiple usage buildings in total building stock (%, 'm'), (x) diversity in building use ('u'), (xi) municipal town plan enforced in law (dummy variable, 'o'), (xii) average elevation (m, 'Ele'), (xiii) proximity to the sea coast line (dummy variable, 'Sea'), (xiv-xix) distances from Athens ('dAth'), Piraeus ('dPir'), Maroussi ('dMar'), Markopoulo Messoghias ('dMak'), Aspropyrgos ('dAsp') and Oropos ('dOro'), intended as relevant urban centers (or sub-centers), (xx) municipal size (log ha, 'Area'), (xxi) Soil quality index ('Sqi') and (xxii) Climate quality index ('Cqi'). Distances from urban centers and sub-centers mentioned above were calculated as the linear distance between the relevant municipal centroids. This analysis provided a generalized picture of spatial relationships, distances and accessibility characterizing the study area (Salvati and Serra, 2016). The adopted indicators provide a comprehensive overview of rapidly evolving socioeconomic conditions in Athens' fringe over the entire study period. Since they were derived from statistical data, mainly from national censuses of population and agriculture, indicators' homogeneity, representativeness and comparability over time is the highest possible within quantitative information provided by official statistics. The number of municipalities in the study area was increasing slightly over the time period stabilizing at the actual number in 1971 and 1981. In this regard, a full indicators' database was developed covering all the spatial domains for six points in time, from 1961 to 2011. The few missing data were filled considering (i) the value observed for the same municipality ten years later, (ii) the values of the four neighboring municipalities and (iii) the cross-section, average value of the same indicator in the entire study area.

The spatial distribution of the main indicator adopted in this study (population living in sparse settlements) was illustrated using maps and descriptive statistics. A step-wise multiple regression

analysis was run to identify relevant factors shaping the spatial distribution of sparse population over time, considering the percent share of population living in sparse settlements in total resident population as the dependent variable and the background indicators described as predictors. A forward step-wise approach was adopted with the aim to identify the most relevant, non-collinear predictors within the broad set of candidate variables potentially influencing the spatial distribution of sparse population. Predictors were selected by fixing a F-to-enter threshold to 5 and a F-to-remove threshold to 2.5. Only models with significant adjusted R2 and predictor's coefficients were considered in the final analysis. Adjusted R2 and Durbin-Watson test for serial correlation were evaluated when assessing the goodness-of-fit of each model selected in the forward step-wise procedure. To reduce the impact of (intense) deviations from normality, variables were standardized prior to analysis.

Figure 4.29 illustrates the spatial distribution of sparse settlements in the study area at the beginning and the end of the investigation period. In 1951, sparse settlements were distributed in a heterogeneous and fragmented way across the Athens' metropolitan region, being in both the peri-urban fringe around Athens and in more remote and rural sites of northeastern Attica. With urban expansion, sparse settlements in 2011 were observed progressively far away from Athens, concentrating along the Aegean Sea coastline in northern and Eastern Attica, at distances ranging between 30 km and 40 km from downtown Athens. Such transformations are coherent with the progressive expansion of residential settlements involving traditionally rural municipalities in the outskirts of Athens.

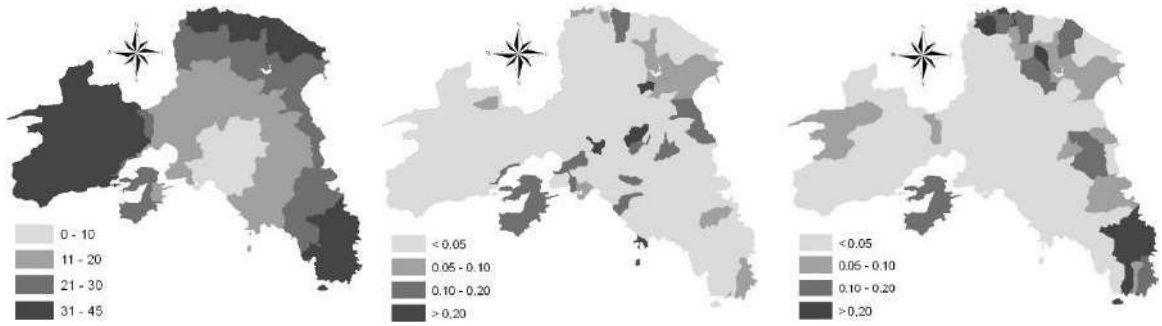

Figure 4.29. Average linear distance of each municipality to downtown Athens (left). Density of sparse settlements (per km²) in the study area (middle: 1951; right: 2011).

Figure 4.30 illustrates the progressive decline of sparse population in the study area between 1961 and 2011. Percent share of population living in sparse settlements in total resident population at municipal scale decreased continuously over time (from more than 30% in 1961 to less than 10% in 2011). Spatial variability in this indicator declined over time, being the lowest in 2011, when municipalities with more than 30% population living in sparse settlements were rather scarce compared with 1961, when municipalities with sparse population >50% of total population were relatively common in both rural districts and areas around Greater Athens. The spatial distribution of population living in sparse settlements was relatively radio-centric, increasing with the distance with downtown Athens and being negatively influenced by topography and road accessibility (Figure 4.31). Sparse settlements were relatively common in all municipalities around Greater Athens in 1961 and decreased in number and population size in the following two decades. Since 1991, population in sparse settlements remained higher than 60% of total population only in scattered municipalities southeast and west of Athens, especially in rural and economically-

disadvantaged districts of Thriasio-Megara (Western Attica) and Keratea-Lavrio (Eastern Attica). In 2011, only a few municipalities located in Northern and Eastern Attica had a share of population living in sparse settlements above 30%.

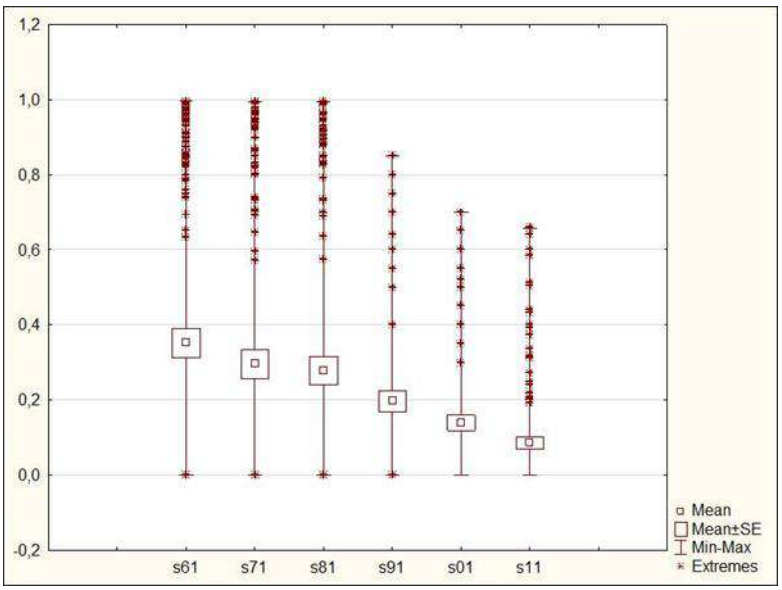

Figure 4.30. Box and Whisker diagram illustrating the statistical distribution of the dependent variable (relative proportion of population living in sparse settlements in total resident population at the municipal scale, namely 's61', …, 's11') in the Athens' metropolitan region, selected years from 1961 to 2011.

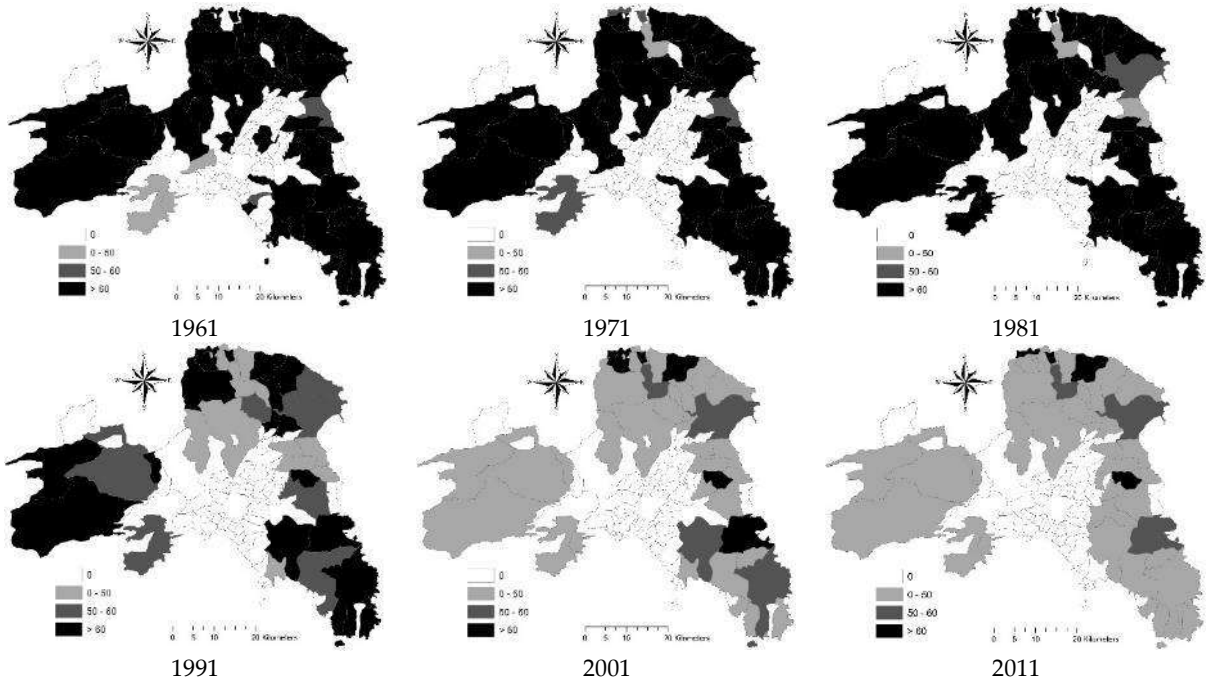

Figure 4.31 Percent share of population living in sparse settlements in total resident population by year and municipality, Athens metropolitan region.

4.7.2. Socioeconomic predictors of sparse population

Table 4.20 illustrates step-wise regression models identifying the most relevant predictors that may explain the spatial distribution of sparse population in metropolitan Attica over the study period. Models received relatively high adjusted R2 all over the study period, increasing from 0.45 in 1961 to 0.51 in 2011 and reaching a peak of 0.55 in 2001. Values of the Durbin-Watson test were

systematically close to 2, indicating a negligible serial autocorrelation. Distance from downtown Athens was the most significant predictor over a relatively long time period between 1961 and 1991, indicating the predominance of a radio-centric expansion that preceded a more latent phase of dispersed urban growth. The regression coefficient for this predictor was the highest in 1971 (reflecting the particularly compact and hyper-dense structure characterizing the Greater Athens' area in that period) and declined moderately afterwards. Distance from Markopoulo Messoghias, the main center in the Messoghia district, was negatively associated with sparse population. Regression coefficients were particularly high at the beginning of the study period, decreasing progressively in more recent decades, except for 2001. Municipal size is another predictor associated positively with sparse population. Municipalities administering a larger area-that are usually destined to non-urban use, such as cropland or forests-had a larger density of sparse settlements. Tourism specialization and average farm size were predictors related positively with sparse population only in 1961.

Table 4.20. Results of step-wise multiple regression models with background socioeconomic variables as predictors of population living in sparse settlements (dependent variable) in the study area by year (significance at * $p < 0.05$, ** $p < 0.001$; SE means standard error).

Variab.	1961				1971				1981			
	B	SE	$t_{(108)}$	*p*	B	SE	$t_{(110)}$	*p*	B	SE	$t_{(110)}$	*p*
dAth	0.905	0.236	3.84	0.0002 **	1.056	0.231	4.56	0.0000 **	0.998	0.225	4.44	0.0000 **
Area	0.332	0.081	4.12	0.0001 **	0.339	0.080	4.23	0.0000 **	0.390	0.078	5.00	0.0000 **
dMak	−0.620	0.187	−3.31	0.0013 *	−0.632	0.186	−3.39	0.0010 *	−0.630	0.181	−3.48	0.0007 **
dAsp	−0.483	0.207	−2.33	0.0215 *	−0.531	0.206	−2.58	0.0112 *	−0.478	0.200	−2.39	0.0186 *
t	0.190	0.070	2.71	0.0079*								
Afs	0.190	0.082	2.31	0.0226 *								
Adj-R^2	0.454				0.455				0.486			
DW test*	1.90				1.98				1.91			
	1991				2001				2011			
	B	SE	$t_{(110)}$	*p*	B	SE	$t_{(110)}$	*p*	B	SE	$t_{(108)}$	*p*
dAth	0.663	0.081	8.18	0.0000 **								
Area	0.362	0.076	4.75	0.0000 **	0.318	0.073	4.34	0.0000 **	0.412	0.107	3.85	0.0002 **
dMak	−0.368	0.089	−4.15	0.0001 **	−0.740	0.109	−6.76	0.0000 **	−0.358	0.203	−1.77	0.0800 *
dAsp									0.307	0.149	2.06	0.0414 *
dOro	−0.189	0.077	−2.47	0.0149 *	−0.758	0.100	−7.58	0.0000 **	−0.734	0.123	−5.98	0.0000 **
dMar					1.000	0.106	9.39	0.0000 **	0.566	0.218	2.60	0.0107 *
Ele									−0.275	0.099	−2.78	0.0063 *
Adj-R^2	0.535				0.548				0.509			
DW test*	1.96				1.97				1.96			

* Durbin-Watson statistic results

Between 1961 and 1981, distance from Aspropyrgos, a rural center in Thriasio district, was negatively associated with sparse population as observed for the distance from Markopoulo Messoghias. Interestingly, the same predictors displayed a positive relation with the dependent variable in 2011, outlining the impact of recent urban expansion, since Aspropyrgos became a peri-urban municipality with mostly compact and semi-dense settlements in recent decades, progressively losing its rural characteristics. Distance from a rural place such as Oropos (Northern Attica) was a significant predictor of sparse population (negative coefficient) only since the early 1990s. At the same time, distance from Maroussi (the new business district northeast of Athens) became an important predictor of sparse population (positive coefficient) in 2001 and 2011. The

analysis clearly outlines how long-term urban dynamics (and especially radio-centric growth of Athens in the earlier decades) have influenced the empirical results of the models.

4.7.3. Sparse settlements and the evolution of socio-demographic local context

Multifaceted processes of landscape 'co-evolution' among urban expansion and peri-urban contexts around metropolitan areas have been identified over the last decades, leading urban and rural elements to coexistence and latent conflicts (Moissidis and Duquenne, 1997). Landscape transformations were more intense in local contexts where resident population increased quickly due to suburbanization processes and where ecosystems are more fragile due to specific land conditions (Ferrara et al., 2015; Kizos and Vakoufaris, 2011; Kristensen et al., 2001; Sabbi et al., 2015; Aretano et al., 2013; Beriatos and Gospodini, 2004; Biasi et al., 2015; Cimini et al., 2013; Cohen et al., 2015; Economidou, 1993; Raudsepp-Hearne et al., 2010; Salvati et al., 2014; Tsilimigkas and Kizos, 2014; Vieri, 2002; Zambon et al., 2018; Barbati et al., 2013). Related to this, the Attica region experienced soil consumption and rural changes producing negative environmental externalities (Salvati et al., 2015; Salvati, 2013; Orsini, 2013). Furthermore, in recent years with economic crisis, a small but increasing number of residents in Greek cities (especially in Athens and Salonika) declares the willingness to leave their city with the purpose to work in the primary sector (Gkartzios, 2013; Moissidis and Duquenne, 1997).

In this line of thinking, sprawl dynamics led to a new form of peri-urban landscape, possibly associated with a new definition of 'rurality'. In 1951, the spatial distribution of sparse settlements was heterogeneous and fragmented across the Athens' metropolitan region; sparse settlements were located in both the peri-urban fringe around Athens and in more remote and rural locations of northeastern Attica; in 2011, sparse settlements were exclusively found far away from Athens, being concentrated along the Aegean Sea coastline in northern and Eastern Attica (Zitti et al., 2015). Furthermore, spatial variability and percent share of population living in sparse settlements in total resident population at a municipal scale decreased continuously over time. Spatial variability was the lowest in 2011, when municipalities with more than 30% of population living in sparse settlements were rather scarce compared with 1961, when municipalities with sparse population >50% of total population were relatively common in both rural districts and peri-urban areas around Greater Athens.

The empirical results of the study contribute to understanding a complex mechanism of urban/rural development involving sequential stages of metropolitan growth (compact expansion, dispersion, re-densification, etc.) seen from the 'other side of the fringe', i.e., considering the increasing landscape mix in rural districts now becoming more mixed and entropic, as typical of many peri-urban areas across Europe and in other advanced economies. Athens has experienced one of the fastest expansions of resident population, income and dispersed settlements in southern Europe (Gargiulo Morelli et al., 2014; Kallis, 2010). Related to this, the regression analysis offers a more comprehensive interpretation of Athens expansion and changes in the related socioeconomic context providing evidence of the dominance of a typical radio-centric structure up to the 1990s and the emergence of new settlement forms-oriented toward urban dispersion-in the following decades. Distance from Athens resulted in the most relevant predictor of the spatial distribution of sparse population between 1961 and 1991, demonstrating the prevalence of a radio-centric development that preceded a more latent phase of dispersed urban growth, being more influenced by spatial

proximity and elevation. Since 1991, sparse settlements were concentrated in southeastern and western municipalities near Athens; in 2011, only a few municipalities located in Northern and Eastern Attica had a share of population living in sparse settlements above 30%. At the same time, new distance indicators (e.g., distance from Maroussi) became significant in 2001 and 2011, suggesting the role of processes of residential and economic dispersion in delocalized places.

The spatial gap among the metropolitan area of Athens and the rest of Greece, and even among the city of Athens with respect to its metropolitan area, brings out a territorial polarization that expresses a set of factors that justify the uneven socioeconomic disparities between urban and rural areas, almost because of the consolidated dominance of Athens over the metropolitan hierarchy (Souliotis, 2013; Rontos et al., 2017). The Athens' metropolitan region was traditionally organized in a mono-centric structure (Zambon et al., 2017), where urban settlements are concentrated around the capital city, and rural areas extend the remaining part of Attica (Colantoni et al., 2017; Moissidis and Duquenne, 1997). A trend toward discontinuous urban expansion was detected since the 1980s in Athens (Delladetsima, 2006; Giannakourou, 2006), with occurrence of medium-low density settlements (Arapoglou and Sayas, 2009; Chorianopoulos et al., 2010; Cuadrado-Ciuraneta et al., 2017). Distance from other centers (e.g., Markopoulo Messoghias) was negatively associated with sparse population. In addition, municipal size is positively associated with sparse population since larger municipalities may state more permits for sparse buildings.

Between 1961 and 1981, distances from the rural centers of Aspropyrgos and Markopoulo Messoghias were negatively associated with sparse population. The same predictors in 2011 displayed a positive relation with the dependent variable, outlining the impact of recent urban expansion, since Aspropyrgos became a peri-urban municipality with compact and semi-dense settlements, progressively losing its rural characteristics. Distance from a rural place, e.g., Oropos (Northern Attica), was a significant predictor of sparse population (negative coefficient) only since the early 1990s. Distance from Maroussi (the new business district north-east of Athens) became an additional predictor for sparse population in 2001 and 2011. The analysis clearly outlines how long-term urban dynamics (and especially the radio-centric growth of Athens) seriously affected the empirical results of the regression models.

Based on these premises, spatial planning should find a joint vision of spatial, economic and social combination among ‘rurality’ and industrial modernity (Fregolent and Vettoretto, 2017). By proposing new forms of sustainable development in traditional contexts (Zambon et al., 2018), a new concept of ‘rurality’ should be increasingly faced with current landscapes that mix scattered settlements and fragmented cropland and are exposed to increasingly volatile economic downturns (Boubaker et al., 2016; Delfanti et al., 2016; Colantoni et al., 2013; Monarca et al., 2008; Di Felice et al., 2014; Ferrara et al., 2014; Monarca et al., 2011; Colantoni et al., 2012; Giourga and Loumou, 2006; Marchetti et al., 2015; Marucci et al., 2018; Nuissl et al., 2009; Pili et al., 2017; Salvati and Carlucci, 2011; Zambon et al., 2016; Zambon et al., 2017; Monarca et al., 2011; Corona, 2015). In this regard, rural development is increasingly constrained by competition with non-agriculture, productive land-use (e.g., residential and industrial settlements, infrastructure and logistics). General principles of rural development in mixed peri-urban districts indicate that a stable and balanced socioeconomic local context is a key component when endorsing an effective and sustainable use (Zitti et al., 2015), which depends on different interacting elements of local sustainability, including demography, environment, social cohesion and poverty alleviation (Salvati, 2014; Giannakourou, 2005). In the

study area, rural development issues add to a relatively complex mechanism of urban expansion, based on planning deregulation, ineffective zoning and informal building at least up to the late 1980s. More recent strategies of spatial (town and regional) planning have indicated a clearer direction toward centralized and formal zoning rules and land management, e.g., introducing planning constraints to building in rural areas and a stricter regime of environmental protection addressing national and European regulations (Tsilimigkas et al., 2015; Kizos et al., 2017). Implications of the study are important when designing strategies for sustainable urban form and promoting urban containment in de-regulated metropolitan contexts.

Spatio-temporal dynamics of sparse settlements may reflect resilience and compliance of Mediterranean peri-urban landscapes to rapidly-changing socio-demographic circumstances over time (Salvati et al., 2017; Ceccarelli et al., 2014). Based on this framework, territorial heterogeneity, topographic complexity and urbanization-driven land fragmentation are a pertinent challenge for policy makers and land managers (Amato et al., 2016; Amato et al., 2018; Aubry et al., 2012; Audsley et al., 2006; Biasi et al., 2015; Kelly et al., 2015; Mosquera-Losada et al., 2016; Paul and Haslam Mckenzie, 2013; Serra et al., 2014). Under the assumption that regional transformations influence (positively or negatively) local socioeconomic systems, the resulting environmental conditions require extensive monitoring and spatially-explicit policies derived from a comprehensive socio-ecological vision. In this line of thinking, landscape transformations can be more effectively governed by multi-level policies joining short-term and long-term socioeconomic goals, including short-term economic cycles (expansion vs. recession) and structural changes covering a longer time horizon.

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5. Environmental threats and soil consumption

The concept of environmental risk - hardly measurable and unstable over time and space - is often intended as a notion with an immediate spatial and temporal dimension - although with sometimes unpredictable off-site effects. While spatial analysis shares some key tools with other disciplines, scale, process, gradient, sustainability and policy are often seen as unique concepts in regional science. These crucial notions form a substantive basis for comprehensive knowledge of vastly different biophysical and socioeconomic contexts. Emphasis is given to (i) the political, social, demographic and economic processes that affect Land Degradation (LD), (ii) the environmental consequences on Mediterranean landscape, (iii) the implications of LD on local communities and (iv) the potential response that societies can implement to limit the impact of LD (Briassoulis, 2005; Salvati, 2010).

5.1. Land quality and desertification risk

Land Degradation and Desertification are recognized as leading processes of natural resource depletion and is one of the most important issues in the political agenda for the 21st century (Stringer, 2008; Grainger, 2009). Identified as a long-term decline in land productivity and ecosystem functions, LD is expanding at the global scale: according to FAO (2003), 30 percent of forest land, more than 20 percent of cultivated areas and 10 percent of grasslands have undergone recent processes of degradation. LD is becoming more serious in developed countries and especially in some parts of the Mediterranean basin (Rubio and Recatala, 2006) due also to climate change and growing human pressure. The concept of Land Degradation should be split from that of desertification (United Nations 1977), which is a specific type of LD implying the irreversible (or hardly reversible) loss of capability for a sustainable agricultural and forestry production (Fantechi et al., 1995). The most widely accepted definition of "desertification" is the one given by United Nation Convention to combat Desertification (United Nations 1977): 'land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities'. LD is perceived as a major threat worldwide since it determines long-term decline in land productivity and weak socio-environmental sustainability (Steer 1998; Conacher, 2000). LD impacts soil fertility but also involves ecological and economic processes that characterize the ecosystem at different spatial scales. In fact, areas vulnerable to LD expanded rapidly in southern Europe (Conacher and Sala 1998).

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LD in wealthier countries is a clear example of the interaction among ecological, economic and social systems (Puigdefabregas and Mendizabal, 1998; Johnson and Lewis, 2007) and is determined by the interaction of proximate causes and underlying factors (Perez-Trejo and Clark 1996; Thornes, 04; Ibanez et al., 2008). It suggests that (global and regional) socio-economic processes are driving forces for a LD (Herrmann and Hutchinson, 2005). The complexity of this phenomenon represents a limitation for both the empirical approach and the development of efficient policy strategies (Glenn et al., 1998). Nevertheless, the increasing interest for socio-economic aspects involved in the LD problem is recently pointed out in several contributions (Gisladottir and Stocking, 2005; Wilson and

Juntti, 2005). In fact, especially in past decades in the European Mediterranean areas, the widespread land-use transformations depended not only on urbanization, industrialization and agricultural mechanization but also on depopulation, economic marginalization and land abandonment of rural areas, at times accompanied by local processes of soil erosion (Salvati, 2014).

To get light in the over mentioned processes and possible interactions among them, this work discusses the most important causes and consequences of Land Degradation (LD). It especially raises issues related to social, economic, cultural, institutional and ecological matters to achieve a sustainable development capable to minimize the risk of LD in the Mediterranean region. Although extensive literature investigates the relationship between LD processes and selected socioeconomic drivers in threatened countries (e.g. Africa, China, Australia and south America), a comprehensive framework is not yet available for southern European region, which shows increasing vulnerability to desertification (Wilson and Juntti, 2005; Montanarella, 2007).

The importance of soil degradation in LD has been widely recognized since it appears to be the end results of climatic, soil and vegetation processes (e.g. Kosmas et al., 2000a) and claims important interactions with the socioeconomic dimension (Wilson and Juntti, 2005). As an example, deforestation leads to an increased overland flow since it removes vegetation which probably affects rates of runoff more than any other single factor (Kosmas et al., 2000b). The complex system determined by environmental conditions and their interaction with socioeconomic processes, makes difficult the search of scientific approach, requiring particularly the development of both sophisticated analytical procedures and suitable policy strategies (Steer 1998). Salvati and Zitti (2007) suggest that ecological and economic factors contribute differently to LD, creating a complex spatial and temporal pattern of environmental degradation along the elevation gradient. The ecological consequence of such dynamics is measurable in terms of increasing disparity in land vulnerability due to unbalanced resource availability which contributes to unsustainable regional development. Consequently, challenges such as regional socioeconomic disparities and pressures on the natural heritage require an integrated policy response at both national, regional and local scale (e.g. Neumayer, 2001; Drake and Vafeidis, 2004). Although several southern European countries show a high level of economic development, important regional disparities still exist at the local scale. For instance, disadvantaged rural areas in the south of Spain, Italy and Greece exhibit critical environmental conditions (Briassoulis, 2004), claiming for important, renewed policy interventions from both the environmental and socioeconomic side (Wilson and Juntti, 2005).

Building-up adequate methodologies to assess the relationship between environmental, economic and social factors is recognized as a difficult task due to the heterogeneity of cause-effects relationships and the linkage between LD and human activities (Rubio and Bochet 1998; Kosmas et al., 2003). A multiplicity of data sources is currently used to develop an information system based on statistical indicators and representing human-induced LD trends (Rubio and Bochet 1998). The recognition, quantification and spatial representation of complex processes such as LD may benefit of a multidimensional and multi-temporal approach to assess vulnerability to LD, addressing quantitatively structural changes occurred in southern European areas. Based on these assumptions, LD processes need to be analyzed in terms of worsening land resources (Rubio and Bochet 1998; Montanarella, 2007). Therefore, LD generally means the temporary or permanent decline in the productive capacity of the land (Fernandez, 2002). Far from being a simple process with clear outcomes (e.g. Thornes, 2004; Ibanez et al., 2008), its complexity can be appreciated by both field

assessors and planning actors (Glenn et al., 1998; Herrmann et al., 2005; Gisladottir and Stocking, 2005; Veron et al., 2006).

5.1.1. Regional framework

Quantitative assessment and spatial representation of environmental quality and ecological risk may benefit from a division into homogeneous regions. The definition of 'region' mainly depends on the argument of study, the sensibility of the researcher and the availability of quantitative information. Improvements in Geographic Information Systems (GIS) and data mining procedures that facilitate the use of multivariate analysis for defining regions has raised demands for geo-referenced digital data, appropriate spatial tagging and consistency in area definitions (van Delden et al., 2007). The interest in procedures analysing regional situations and implementing effective policy strategies arises in different ecological fields. A multidisciplinary approach based on the analysis of multiple driving forces involved in these processes is required to achieve a correct evaluation of environmental quality and degradation, as well as their relationship with the economic and social system (Dumanski and Pieri, 2000).

The discussion of some important aspects of LD contributes to the design of policies for the sustainable development of the Mediterranean region. Due to the several factors involved, a 'methodological risk' may arise when missing some key messages coming from the changing landscape. In this sense, suitable indicators make sure the most effective use of the accessible data (Rubio and Bochet 1998; Kosmas et al., 2003). Their versatility allows relatively easy integration with data produced over different methodologies, including remote sensing and field measurements. One problematic example related to the concept of 'region' is the choice of key environmental indicators. Indicators can be classified into two hierarchical groups, namely (i) 'hard indicators' and (ii) 'soft indicators', that give a mixed selection strategy. Hard indicators are indicators with a well-documented connection with LD and validated by field studies. Soft indicators are those usually not included in multi-dimensional models of land vulnerability. These indicators show an indirect link with LD and could be defined as 'contextual indicators. Soft indicators are useful when defining the environmental conditions of land vulnerability based on the results of quantitative analyses. Although assessment frameworks regarding the areas of the Mediterranean have been developed, there is certainly scope for technical improvements. Working on various spatial levels, especially at the local scale, is useful to investigate into the set of variables assessing land vulnerability and by collecting long time series of suitable indicators. Providing spatial information regarding the rate of LD and the variation of relative anthropogenic reasons might correspond to a tool for drawing political performance able to efficiently contrast LD processes at regional scale (Briassoulis, 2004).

5.1.2. Scale

Scale can be declined into different research dimensions: time and space. The set of definitions argued so far is tailored for evaluations produced at large scale but is vague for studies at regional or local levels. The scaling down needs a more detailed conceptual framework along with definition of areas prone to desertification (Enne and Zucca, 2000). Different concepts of desertification were therefore proposed according to landscape characteristics and geographical scale (Lambin, 1993). As an example, strictly desert lands, which are relatively scarce in southern Europe, are considered as tracts of land happening in dry climates and demonstrating 'functional sterility', that areas where agriculture and forestry are currently no longer either economically or ecologically sustainable

(Thornes and Brandt, 1996; Conacher and Sala, 1998). This concept could be associated to vulnerability and sensitivity to LD processes. Vulnerable lands indicate that their environmental characters are like that of deserted contexts, but several factors (e.g. vegetation cover, climate, agriculture, irrigation) successfully mitigate LD processes (Geeson et al., 2002).

Due to the lack of a unifying database integrating time series, scenarios and quantitative data of sensitive areas on a country or supra-national scale, a permanent assessment of the biophysical and socioeconomic conditions leading to LD over large areas should therefore be a major concern (i) to guide research investigating the particular processes concerned LD at the local scale and (ii) to identify and organize a variety of measures with the final aim of obtaining a complete policy framework against desertification at the regional scale (Lambin, 1993). It is widely assumed that similar rules in the environment-economy relationship may apply irrespective of spatial scale, thus leading to the use of the same framework to explore (and of the same model to explain) spatial agglomeration, territorial specialization and the negative environmental externalities of economic production at vastly different scales. The notion of geographical scale operationally provides meaningful insights when understanding (i) the effect of some socioeconomic and environmental gradients that clearly account for the spatial distribution of natural resources and their potential degradation, (ii) the impact of globalisation/polarisation/localisation of the economic activities and their potential effects on the environment, to be included in this issue the role of the scale of production from a spatial perspective and (iii) the role of decentralisation in (multi-scale and multi-tasking) environmental policy matters.

The interaction of biophysical patterns with socioeconomic factors should be therefore assessed to delineate areas potentially exposed to desertification. Composite indexes of land vulnerability have been proposed but only some studies have attempted to quantify, in vast territories, time changes in LD. In such a context, (i) moving from cross-country to single-country studies mitigates the problems associated with data comparison from different countries and (ii) focusing on scale issues allows to empirically analyses environmental phenomena whose knowledge may be influenced by the level of observation, because they generally depend on drivers acting at different spatial scales (e.g. Papyrakis and Gerlagh, 2007). Dynamics of convergence (or divergence) in the level of land vulnerability to degradation reflect the effect of long-term path of (sustainable) regional development in the light a specific environmental process. Convergence in desertification risk could be a scale-independent phenomenon. It was then argued that a multi-scale policy strategy, based on integrated actions at both national, regional and local levels, may be effective in contrasting land degradation in southern Europe (Glenn et al., 1998; Herrmann and Hutchinson, 2005).

5.1.3. Sustainability

In the vast literature on the issue, LD is approached at the 'on site' scale with specific attention to the biophysical causes; few studies deal with the phenomenon at a regional scale looking for the human factors and their interaction with the biophysical processes of LD. The debate on 'sustainable development' vs economic growth (Galeotti, 2007), which is linked to this matter, interprets the interaction between biophysical and socioeconomic factors as a complex limit for understanding (Steer, 1998). The interest for the analysis of socioeconomic drivers of LD is increasing, as some studies show from both the empirical and theoretical points of view. It is known that the sustainability of land resource management depends on a series of factors of political, economic,

social and ecological nature (Puigdefabregas and Mendizabal, 1998). Especially from the economic side, one of the possible responses to environmental degradation and natural resource depletion is sustainable growth (Steer, 1998). Themes of economic performances and development, social inequality, institutional policies and their relations with environmental quality and degradation provide key examples of the interaction between immediate causes and background factors of composite ecological phenomena (e.g. Singh and Singh, 1995; Barbier, 2000). It is thus important to identify the processes which act as proximate causes from those representing underlying factors of environmental degradation and to disentangle short- and long-term effects.

A greater knowledge of LD through an exploratory analysis may highlight the most significant factors underlying this environmental process. The choice of the (empirical) model and the selection of the different kinds of variables that possibly interact in the process of LD add some suggestions to the debate about the relationship between environment and development. In particular, the outcome of economic models demonstrates that: i) the relationship between environment and development is composite and should be approached out of simplification; ii) especially when could affect policy and planning processes, any analytical approach must consider at least the three main components (economic, social, and environmental) of development; iii) the framework of sustainable development is therefore the only one that can still solve the environment vs development dilemma (Salvati, 2014).

An exploratory framework may provide outputs representing the basis for more detailed, sophisticated models (Aldy, 2006, 2007; Camarero et al., 2008). Regional convergence in key environmental processes such as land vulnerability to degradation was analyzed at homogeneous scales from the economic, ecological and institutional points of view, based on the characteristics of the studied areas. Frameworks were proposed to interpret convergence and its consequences for sustainable development and environmental quality (Salvati and Zitti, 2007), the formation of regional disparities and the design of drought contrasting strategies (Wu and Wilhite, 2002), with policy implications clarified in terms of rural development and sustainable growth (Glenn et al., 1998; Herrmann and Hutchinson, 2005), spatially balanced and consistent over time (Zuindeau, 2007). In the light of complex environmental processes which are difficult to be monitored and modelled due to the intimate relationship among the several involved factors, sustainable development is intended as spatially balanced and consistent over time (Salvati, 2014).

5.1.4. Policy

Human abuse or misuse of land generates regional disparities, being an important cause of LD (Salvati and Zitti, 2007). In what measure human-related spatial dichotomy affect LD levels and which processes linking social inequality to environmental quality can have an impact on LD and desertification has been not completely ascertained. Objectives of territorial cohesion were added to the more traditional targets of social and economic cohesion in EU policy (Tumpel-Gugerell and Mooslechner, 2003). Renewed interests in territorial matters suggest that challenges such as regional disparities and environmental pressures require an integrated approach aimed to monitor their impact and a common European-wide policy response (Drake and Vafeidis, 2004) for a discussion on desertification matters).

Social policies typically impact LD and desertification risk because of the evident human dimension and implications of such measures in terms of adaptation and mitigation to global

changes. The formulation and implementation of social policies to eradicate poverty and mitigate social inequality, especially in rural and economically-marginal areas, is crucial for the creation of a sustainable and equitable socioeconomic environment. Only in such environments people can understand, accept and participate to the implementation of environmentally-friendly policies and practices. Different examples of social policies with an indirect feedback on the LD process may be recalled here. First, as social inequality, poverty and especially rural poverty are in most cases gendered phenomena, policies of equitable participation of women to economic and social life are needed as a part of the wider set of policies aimed to alleviate poverty and social exclusion. Second, social policies with emphasis on human resource development (especially in the agricultural sector), are necessary with education and training schemes designed to address a sustainable management of land. Third, permanent mechanisms of information dissemination are needed especially in the primary sector. Four, migration policies have to be an integrated part of a set of social policies aimed to combat human desertification in marginal, inland areas (Dimara and Tsokas 1996).

In this ambit, stakeholders' participation in planning strategies against desertification is relevant (Briassoulis, 2004; Wilson and Juntti, 2005). Local changes have greater impact on individual decisions, which in turn affect LD directly or indirectly (Lemon et al., 1994, Loumou et al., 2000, Iosifides and Politidis, 2005; Onate and Peco, 2005; Atis, 2006; Hein, 2007). As observed by Briassoulis (2005), stakeholders have different perceptions of desertification; research is increasingly required to indicate mechanisms aimed at involving stakeholders in problem analysis and solution-finding. It would be also important to establish and intensify the dialogue between stakeholders, policy-makers and the general public. For example, even the agreement on a common definition for 'desertification' is important in this direction and should be definitely discussed in enhanced institutional platforms. Participatory process, research and tools for policy makers should be the enhanced tools for future actions to combat desertification in southern Europe.

The linkage of LD with different kind of socioeconomic processes claims for a comprehensive policy framework. To renew a wide debate on the actual relationship between economic and social factors and LD at both macro- and micro-scale as well as the possible policies able to mitigate drought and desertification effects on the society, is really urgent for southern European countries, also in the light of their sustainable participation in the European integration process.

The analysis of policy's impacts is essential to assess the repercussion for grassroots stakeholders affected by LD. First, formulation of a policy does not necessarily result in a specific impact on the ground. Second, policies may have different explicit and implicit impacts and, third, the dynamic, non-linear nature of the desertification process should be more definitely recognized for implementing truly integrated measures (Thornes, 2004; Ibanez et al., 2008). Results from different case studies suggest that formulation of a policy does not necessarily result in a specific impact on the ground. Moreover, the processes of non-decision-making, non-formulation and non-implementation of policies are to be regarded as tangible policy implementation. For example, the so-called costs of inaction (which is a concept widely used in climate change policy and now a concept of increasing interest also for LD matters) is an issue that has not been sufficiently acknowledged in previous research. As a result, the process of policy implementation should be seen as a relatively fuzzy decision-making spectrum rather than a clear-cut point in time at which a specific decision is being made and put into practice (Briassoulis, 2005).

Policies are sometimes summarized into a multilevel strategy acting at different scales: national, regional, local (e.g. involving municipalities, water consortia, farmers' groups). The key message of previous studies is that policy strategies should evolve from driver-specific to process-specific. In southern Europe, the formation of coastal-inland disparities is an important issue in the mitigation of desertification via formal policies. All the most important degradation systems identified by Montanarella (2007) can be identified along this geographical gradient, representing a set of well-defined causal chains with complex interrelationships among variables.

5.1.5. Desertification

Desertification is linked with some crucial socioeconomic phenomena that are been briefly examined here in the light of sustainable growth and regional science. This relation represents the interplay between underlying factors, driving forces, causes, consequences and implications of the human-nature interaction regarding desertification. LD is a socioeconomic problem especially because the land use and practice of appropriation are 'socially constructed'. Soil productivity and land capacity, cultivations, land use and sustainable development are products of the multiple human-nature interactions. In addition, climatic changes have caused a reduction in soil productivity due to the lack of water resources (Venezian Scarascia et al., 2006) increasing the salinisation risk and reducing the potential agricultural profitability (Atis, 2006; Hein, 2007). The themes of social and economic organization, integration, inequality and political interventions, as well as their relationships with the production and reproduction of LD and desertification must be discussed in connection with the theoretical framework of sustainable development (e.g. Fernandez, 2002; Lewis and Johnson, 2007).

Land degradation and desertification issues have been reframed in the broad framework of regional science using five key-word: process, region, scale, sustainability and policy. In this sense, research has been oriented the socioeconomic causes of LD, requiring a specific focus on issues apparently demised by recent literature, such as the multiple impacts of credit markets, technological change, reduction of social disparities and land tenure on land configuration and its vulnerability to degradation (e.g. Wilson and Juntti, 2005).

Addressing some of the most significant issues of land vulnerability in an included time/space framework, requires permanent monitoring and effective policies. Raising aspects associated with integrated ecological and socioeconomic matters to reach a decrease of regional disparities and sustainable development path stands for a meaningful tool for both monitoring policy implementation and strategies in ecologically weak Mediterranean regions (Steer 1998; Dumanski and Pieri, 2000; Zalidis et al., 2002; Veron et al., 2006). Environmental degradation causing uncertainty in path trajectories (Thornes, 2004) is becoming a key concept when disentangling the interactions among ecological factors, economic performances, cultural/social dynamics and political actions (e.g. Ibanez et al., 2008).

Structural changes may positively influence environmental quality thus reducing vulnerability to LD. This is not the statement that policies supporting the economic development alone are sufficient to mitigate LD processes, as additional drivers move to reverse the (potentially) positive effect of economic growth (Spangerberg, 2001). Some of them need efficient policy responses, especially at the regional scale. Integrating measures acting at different spatial scales (e.g. environmental measures applicable at the farm/local level, social measures applicable at the

municipality/district level and economic policies applicable at the regional/national scales) may represent a coherent response positively impacting several interacting factors that exacerbate LD. A coordination of multi-scale (national, regional, local) and multi-target (economic, social, environmental) policies is expected to improve the effectiveness of LD mitigation in the light of sustainable development and regional disparities reduction (Briassoulis, 2004).

Effective measures specifically designed to combat desertification in the Mediterranean basin should contribute to the objective of sustainable growth. Strategies aimed at reducing environmental disparities, especially in rural/marginal areas, are crucial to achieve a sustainable development which maintains high environmental quality and mitigates potential LD (Briassoulis, 2005; Wilson and Juntti, 2005; Salvati and Zitti, 2007). The linkage of LD with population growth, urban-rural dynamics and economic development should definitely orient in the design of a comprehensive policy framework towards sustainable development.

5.2. Land consumption in Europe

Metropolitan regions have experienced relevant territorial and socioeconomic transformations occurred throughout the world in recent decades (Salvati and Gargiulo Morelli, 2014). In the wealthiest countries, urbanization can be defined as one of the most important factors concerning landscape change (Antrop, 2004), because of mixed and dispersed expansion patterns (Schneider and Woodcock, 2008; Solon, 2009). Compact urbanization was typically associated with settlement concentration and medium-high levels of population density; while, dispersed urbanization was commonly detected when people are inclined to move toward suburban areas, causing a population decline in inner cities (Zitti et al., 2015).

Considering Europe as the most developed and urbanized continent at the global scale, urbanization-driven land-use changes have determined a progressive decrease of cropland and a moderate expansion of forests and pastures, possibly due to enforced regimes of natural land protection (Haase et al., 2016; Paulsen, 2014). At the same time, urban sprawl became a pervasive phenomenon with relevant implications for both European metropolitan structures and socioeconomic functions (Bruegmann, 2005; Salvati and Gargiulo Morelli, 2014). However, urban sprawl and land-use changes tend to be relatively different in each country, being influenced by place-specific factors associated to geographical, demographic and socioeconomic conditions and the related historical, political and cultural background (Salvati and Gargiulo Morelli, 2014; Oueslati, et al., 2015; Salvati and Carlucci, 2016). Following different countries' perspectives (Haughton, 1999), residential sprawl patterns and processes in most British or French cities appear quite dissimilar from the ones typical of semi-dense, unregulated urbanization models in southern Europe or highly regulated, compact models of eastern European cities (Oueslati, et al., 2015).

Cited article

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Urban sprawl in Europe has been investigated in vastly different socioeconomic contexts (Kasanko et al., 2006; Solon, 2009; Poelmans and Van Rompaey, 2009; Arribas-Bel et al., 2011; Phelps and Parsons, 2003), but relatively few studies have addressed spatial heterogeneity across European countries and/or macro-regions (Oueslati et al., 2015). Such issue is particularly thought-provoking from a normative viewpoint, e.g. the design of effective policies aimed at containing urban expansion (Baing, 2010) or at protecting peri-urban soils from sealing. In this way, a comprehensive investigation of multiple impacts of sprawl on socio-ecological local systems may inform decision-making processes, requiring multivariate approaches based on a diachronic analysis of socioeconomic and environmental indicators (Burton, 2002; Hasse and Lathrop, 2003; Arribas-Bel et al., 2011; Salvati, 2016). Earlier studies demonstrated that urban containment and sustainable land management policies may benefit from a comparative investigation about socioeconomic forces that shape land-use change and soil-use efficiency across European metropolitan contexts (Faludi, 2006).

Assessment of dispersed urban expansion among European countries has been based on approaches and methodologies identifying land-use changes at various spatial and temporal scales (Cheshire, 1995; Couch et al., 2005; Kasanko et al., 2006; Schneider and Woodcock, 2008; Salvati and Gargiulo Morelli, 2014). A comparable analysis of factors underlying dispersed urban expansion

based on standardized data collections is essential for understanding patterns and processes of land-use change with implications for a better comprehension of spatial variability in patterns and processes of urban sprawl in Europe (Cohen and Nijkamp, 2002; Schneider and Woodcock, 2008; Salvati and Carlucci, 2015). Quantitative information dealing with metropolitan land-use change in Europe was mainly based on statistical data with relatively low comparability across countries, except for Corine Land Cover initiative, which have produced multi-temporal land-use maps at 1: 100,000 scales (European Environment Agency, 2006). The European Environment Agency (EEA) recently launched the Urban Atlas (UA) project, which promotes a pan-European land-use assessment that provides comparable, high-resolution maps for Large Urban Zones (LUZ). This geo-database is filling a gap in the data about landscape structure and land-use in a large sample of metropolitan regions in Europe. The boundary of each LUZ outlines the spatial units in the present work. This choice is motivated with the fact that earlier research has successfully explored sprawl processes at the LUZ level. Such spatial unit usually includes suburbs and a considerable part of neighboring rural areas from where sprawl spread out across any metropolitan region (Oueslati et al., 2015).

Besides land-use dataset, thematic statistics are crucial to explore landscape change drivers (Salvati et al., 2016). For instance, socioeconomic, political and cultural factors influence land-use decisions, pondering on definite peri-urban landscape structures (Pinto-Correia and Kristensen, 2013; Hennig et al., 2015). Socioeconomic indicators can be related to each local context, influencing metropolitan structures (Moos and Mendez, 2015). Since population density and per-capita disposable income are positively correlated in urban contexts (Oueslati et al., 2015), the highest values for both these variables were traditionally expected in larger and more compact cities. However, also the (highest level of) personal incomes can be detected in suburban areas (Madden, 2003; Van Der Burgand and Dieleman, 2004). As a matter of fact, long-term suburbanization, typically observed in Europe since the early 2000s, has reflected an increase of affluent population segments settling in suburban locations, emphasizing new residential preferences towards large dwellings in remote and green spaces, also due to a rising car ownership (Turok, 2004; Crols et al., 2017). Furthermore, comparing several European countries, social inequalities have been identified due to relevant income differences among suburban neighborhoods (Hudson and Williams, 1999; Hudson, 2003). Moreover, the shift to capitalism and market economies has widened income disparities. Based on these circumstances, regional transformations relating economic restructuring, demographic structures and urban expansion modes have been less frequently studied in Europe, despite their resulting consequences in terms of socio-spatial imbalances and complex nexus among policy changes, economic spatial restructuring, community marginality and urban sprawl (e.g. Bailly et al., 1996).

Heterogeneous socioeconomic backgrounds in European cities derived also from different historical and political contexts consolidated over time (Salvati and Gargiulo Morelli, 2014; Oueslati, et al., 2015; Salvati and Carlucci, 2016). For example, with compact urban development policies implemented between the early 1970s and the mid-2000s, Netherlands reduced sprawl in peripheral areas, increasing urbanisation close to small villages and towns in central regions (Karst and van Wee, 2006). Central and Western cities are mostly densely populated with moderate sprawl, while in neighbouring regions, such as East Germany, the dispersed expansion of settlements has continued even when population has decreased (Haase et al., 2016). Eastern European countries

have in turn experienced a long transition during the 1990s and the 2000s, when the consequences of depopulation and economic centralization only arose after the fall of the Iron Curtain (Haase et al., 2016). In respect to western and northern Europe, eastern and southern cities have seen a relatively more recent suburbanization, possibly accelerated by rapid demographic changes (Mykhnenko and Turok, 2008).

An exhaustive analysis of land-use change at regional and local spatial scales contributes to find alternative choices better designed for assuring land-use efficiency and long-term sustainability (Giannakourou, 2005; Hoymann, 2011). In this sense, land-use change models have been recently proposed to identify spatial direction and intensity of sprawl phenomena (Poelmans and Van Rompaey, 2010; Crols et al., 2017). Based on such results, European Commission has proposed guidelines and practical tools to reduce land consumption (e.g. European Environment Agency, 2006) with priority actions aimed at containing environmental damages derived from discontinuous urban expansion (Colavitti and Serra, 2017). However, since metropolitan structures in Europe vary from highly compact and dense forms to land-consuming morphologies depending on their relationship with place-specific socioeconomic factors (Weilenmann et al., 2017), the proposed guidelines and tools are considered rather general and with a varying degree of applicability and effectiveness.

Promotion of self-contained urban expansion within a sustainable land management approach needs country-specific strategies adapting to local contexts (Couch and Karecha, 2006; Hewitt and Escobar, 2011). Considering a set of 155 metropolitan regions in six European areas (Western, Atlantic, Northern, Central, Eastern and Southern macro-regions), the work investigates spatial patterns of land consumption across Europe profiling cities according to background variables with the final objective to identify socioeconomic and territorial factors underlying recent sprawl processes at both city and regional level (Salvati and Gargiulo Morelli, 2014). Investigating the characteristic socioeconomic contexts more associated to a high rate of land consumption contributes to design of effective strategies of urban containment adapting to different urban typologies.

5.2.1. Land consumption in 155 European cities

The study investigates a sample of 155 cities representative of 27 European countries (Figure 5.1). Considering the boundaries of European Urban Areas statistical classification (www.urbanaudit.org), the selected areas match with the Large Urban Zones (LUZ) defined by the Eurostat Urban Audit program, providing homogeneous statistical data of European cities at both regional and local levels. LUZs identify areas representing a comparable share of the resident commuting into the city, thus introducing an objective criterion to define urban boundaries from the functional point of view (Eurostat, 2004).

Following Hall and Hay (1980), the investigated cities have been classified into 6 macro-regions: (i) North and Atlantic Europe including Finland, Sweden and Denmark (12 cities); (ii) Western Europe including France, Belgium, Luxembourg and The Netherlands (26 cities); (iii) Germany and Austria, as Central Europe countries (29 cities); (iv) Eastern Europe including Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, and Slovenia (52 cities); (v) the Anglo-Saxon area (22 cities); and (vi) Southern Europe including Greece, Italy, Malta, Portugal and Spain (14 cities).

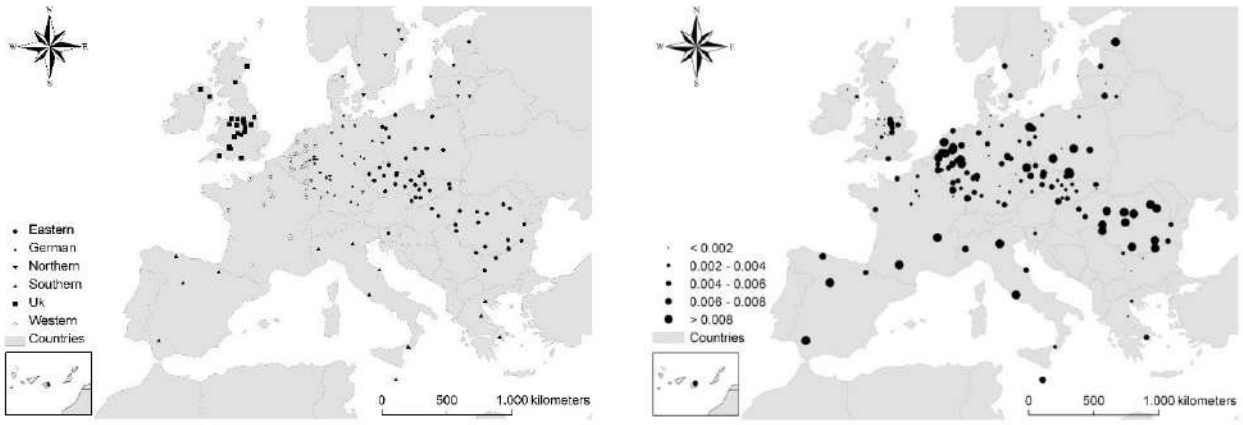


Figure 5.1. The spatial distribution of the 155 metropolitan regions in 6 European macro-regions (left) and the relative proportion of non-urban land converted to built-up area *per year* (right).

A thorough profile of the selected European cities was derived from official data provided by Eurostat and European Environment Agency (EEA) Urban Atlas (UA) program (http://www.eea.europa.eu/data-and-maps/data/urban-atlas). UA investigates land-use in a representative sample of European cities > 100,000 inhabitants within the boundaries of the respective Large Urban Zone (LUZ) based on the definition provided by Eurostat Urban Audit program. UA is a local component of the Global Monitoring and Environmental Surveillance (GMES) land monitoring service providing comparable high-resolution land-use maps for LUZs. For each LUZ investigated, two maps referring to 2006 and 2012 were considered by a spatial overlap of their polygons and attributes, allowing the construction of specific indicators of land-use change. The inner city of each LUZ based on the Urban Audit definition was also considered when calculating socioeconomic and territorial indicators.

UA maps are scaled 1:10,000 with 0.25 ha Minimum Mapping Unit for 'urban' classes (code 1) and 1 ha for 'non-urban' classes (codes 2-5). UA maps distinguish 20 land-use classes, from non-agricultural human activities to cropland, wetland and forests (for a detailed description of UA nomenclature, see European Environment Agency, 2011). UA legend matches completely with CORINE (Coordination of Information on the Environment) land cover nomenclature, which is the most used pan-European land cover geo-database. This study concentrated on UA maps since they assumed a resolution that is 10 times higher than CORINE land cover cartography. UA maps can be elaborated through vector geospatial data, being organized as multiple files including a polygon shapefile, a database file and additional documents with metadata and results of quality checks. Vector geospatial data by LUZ were integrated with statistical data for individual cities derived from Eurostat Urban Audit database providing a variety of socioeconomic indicators for a representative sample of European cities.

Under the hypothesis that socioeconomic factors, land-use composition and landscape structure may affect land consumption patterns across Europe, a total of 41 contextual indicators (7 quantifying land-use change and landscape structure; 19 evaluating land-use composition and 14 assessing socioeconomic characteristics) were collected for each LUZ considered. Indicators of land-use change during the study period (2006-2012) were calculated as percentages of (i) total non-urban land including cropland, forests, pastures and wetlands (codes '2.x', '3.x', '4.x' and 5.x of the UA nomenclature) and (ii) agricultural land (code '2.x') converted annually to urban fabric (code '1.x) in

total LUZ surface and the percentages of (iii) agricultural and (iv) forest land (code '3.x') converted to urban fabric in total LUZ surface undergoing changes in the use of land. Three indicators assessing landscape structure were calculated as (i) mean patch size, landscape-level ('MPS'), (ii) mean patch size, built-up classes with UA codes '1.x' ('MPU') and (iii) ratio between perimeter and surface area of each patch in the landscape ('PSA'). Land-use composition was assessed computing the percent area of 19 UA classes (from '1100' to '3000') (Table 5.1) in total LUZ surface.

Socioeconomic and territorial variables include dummies identifying the geographical position of each city in (i) southern Europe including Italy, Spain, Portugal, Greece and Malta ('SOU'), (ii) United Kingdom ('UK'), Germany and Austria ('GER'), Northern Europe including Latvia, Lithuania, Denmark and Sweden ('NOR'), Eastern Europe including Slovakia, Romania, Poland, Hungary, Czech Republic and Bulgaria ('EAS') and Western Europe including France, Belgium, Luxembourg and the Netherlands ('WES'). Capital cities were identified through a specific dummy variable ('CAP'). Additional indicators were derived from statistical data at the LUZ scale for individual cities assessing total surface area of each LUZ ('SUP'), population density ('DLU'), population growth, 2007-2013 (%) at both LUZ ('PCL') and city scale ('PCC'), City-to-LUZ population percent ratio ('DCL') and per-capita disposable income at LUZ scale ('ILU') and City-to-LUZ income percent ratio ('ICL').

A data mining strategy including Principal Component Analysis (PCA), non-parametric Spearman Rank Correlations (SC) and linear Step-wise Multiple Regression (SMR) was run on individual cities' data with the aim to (i) profile socioeconomic contexts with the highest rate of land consumption through PCA, (i) investigate land-use transformations along multiple gradients using SC, and (iii) characterize the selected urban contexts by way of SMR.

PCA was run on a data matrix containing all indicators for the entire sample of cities, classifying each metropolitan region into a few homogeneous groups. This allows exploring spatial variability in land-use changes assessing which metropolitan contexts have converted more land (especially cropland) into built-up area. Components with eigenvalue > 2 and component loadings > |0.55| were considered in the subsequent analysis.

A comparative analysis identifying the most relevant factors associated with urbanization of cropland and forests was developed using SC testing for significance at $p < 0.05$ after Bonferroni's correction for multiple comparisons. A SMR was finally run with the aim to identify the variables associated with the highest rate of land consumption at individual city level. Predictors were included in the step-wise model when the p-level related to the respective Fisher-Snedecor test was lower than 0.001.

5.2.2. Emerging diversity for land consumption among European countries

Recent expansion of Eastern cities was characterized by the highest (average and maxim) rate of land consumption in Europe (respectively 0.8% and 3.4% per year), followed by Western cities (0.7% and 1.5%) and Southern cities (0.6% and 1.2%). Cities in Germany and Austria experienced intermediate levels of land consumption. Northern European and United Kingdom cities evidenced the lowest level of land consumption on both average and maximum rates over time (respectively 0.3% and 0.8%). In cities where land consumption is the highest, developed land was primarily used as cropland (61%, 59% and 52% of developed land respectively in Eastern, Southern and Western Europe). The reverse pattern was observed in Germany, Austria and Northern European countries.

Table 5.1. Average and maximum values of land consumption indicators (2006-2012) by European macro-region.

Variable	Eastern Europe	Germany and Austria	Northern Europe	Southern Europe	United Kingdom	Western Europe
			Developed land in total LUZ area (%, per year)			
Average	0.8	0.4	0.3	0.6	0.3	0.7
Maximum	3.4	1.2	0.8	1.2	0.8	1.5
			Cropland to built-up area in total LUZ area with changes in the use of land (%)			
Average	61.1	53.3	42.5	59.4	43.8	52.2
Maximum	89.4	78.8	68.6	74.9	71.4	71.0

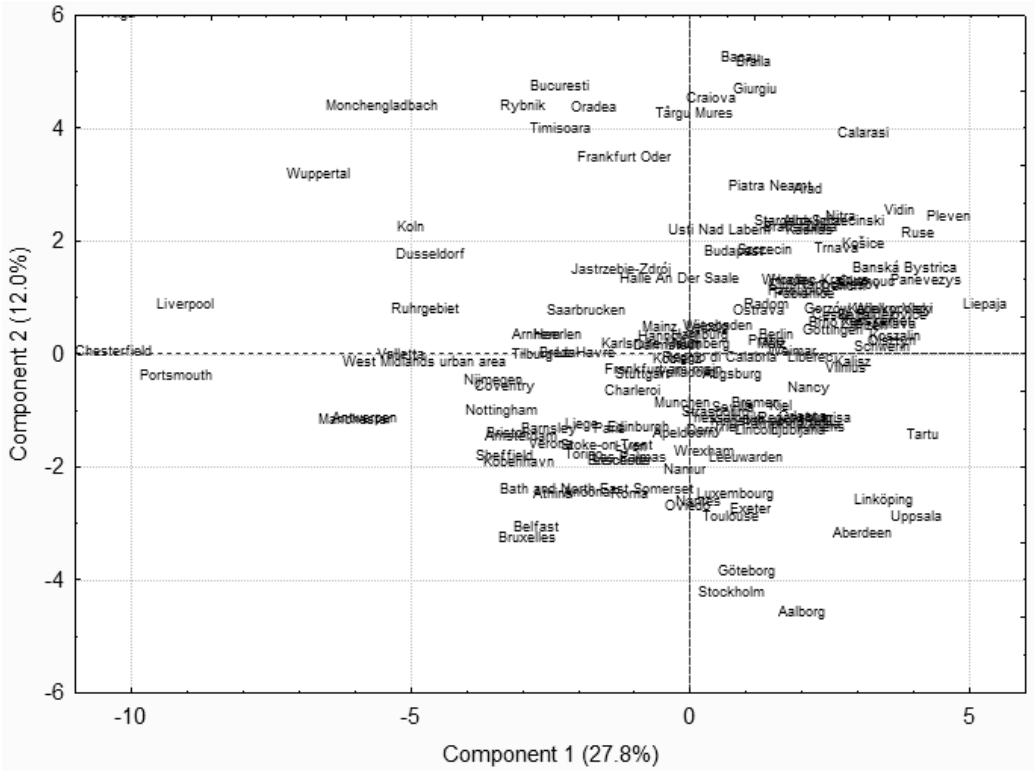
PCA allowed identifying cities with the largest increase of land consumption and their characteristic socioeconomic attributes (Table 5.2). The analysis extracted 4 principal components explaining together more than 55% of the total variance. PC1 accounted for the highest proportion of variance (28%) identifying a gradient of landscape fragmentation (positive and negative loadings respectively attributed to MPS and PSA) which was correlated with population density, and typical urban land-uses such as high- and medium-density residential settlements, industrial settlements, construction sites and urban parks. While not directly associated with land consumption, PC1 demonstrates how landscape fragmentation increased markedly along the urban gradient. Component 2 explained 12% of the total variance distinguishing Eastern European cities with a positive loading (0.6) from cities situated in other European macro-regions. PC2 was correlated positively with land consumption indicators and compact urban fabric and negatively with population growth at city scale and the presence of isolated built-up structures. This axis indicates how in Eastern European cities, land consumption was mainly observed in 'shrinking' metropolitan regions with a compact urban structure. Component 3 explained 8% of the total variance, identifying a gradient opposing United Kingdom cities and very low-density residential settlements. This means that UK metropolitan regions are those with the lowest proportion of discontinuous and sprawled settlements in Europe, a condition possibly linked with specific town planning measures and regional-based socioeconomic and territorial characteristics. Accounting 7% of the total variance, PC4 attributed positive loadings to Southern European cities and cropland extension, in turn correlated with indicators of land consumption. This gradient indicates that Mediterranean cities were exposed to land consumption processes involving specifically agricultural areas. Figure 5.2 illustrates cities' distribution over the four selected axes. PC1 and PC2 discriminates Western from Eastern cities. PC3 and PC4 identified a subtler geographical gradient: several UK cities were clustered in the left-bottom quadrant; northern cities clustered in the right side of the plot. Representative Mediterranean cities were finally grouped in the upper side of the plot.

Table 5.2. Principal Component loadings by variable (loadings > |0.55| were shown; italic indicates PCA supplementary variables; * indicates significance at $p < 0.05$).

Variable	PC 1	PC 2	PC 3	PC 4
Explained variance %	27.8	12.0	7.9	7.2
SOU				0.67
UK			-0.57	
EAS		0.60		
DLU	-0.88			
PCC		-0.72		

1110		0.59	
1121	-0.77		
1122	-0.74		
1124			0.55
1130		-0.55	
1210	-0.91		
1222	-0.83		
1223	-0.64		
1340	-0.66		
1410	-0.84		
1420	-0.83		
2000			0.55
PSA	-0.91		
MPS	0.79		
Developed land in total LUZ area (%)		*0.41**	*0.42**
Cropland to built-up area in total LUZ area (%)		*0.41**	*0.44**

* Variables with non-significant loadings: Ger, Nor, Cap, Sup, PCL, PCC, ILU, ICL, 1123, 1221, 1230, 1240, 1310, 1330, 3000, MPU. Cropland to built-up area in total changed area and forest to built-up area in total LUZ area were not correlated (Pearson linear coefficient) to any principal component.



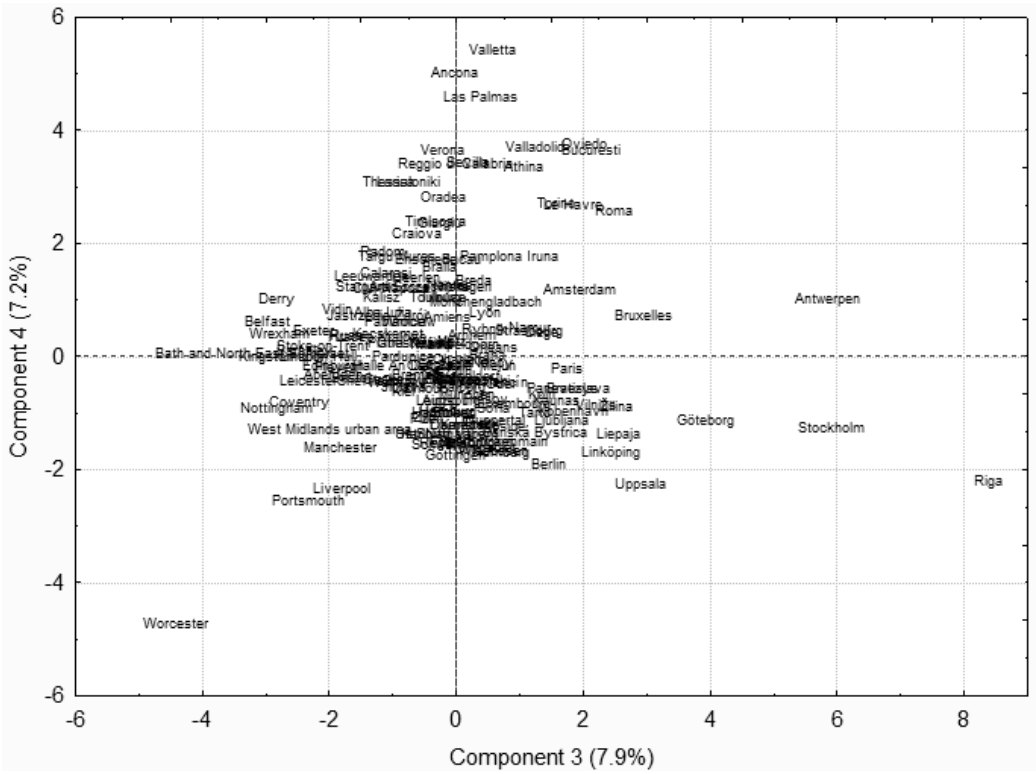


Figure 5.2. Principal Component score plots indicating the position of the studied metropolitan regions in the factorial plane (upper plot: PC1 *vs* PC2; lower plot: PC3 *vs* PC4).

A Spearman rank correlation analysis identified the individual variables most associated with the proportion of developed land in 2006-2012 at the LUZ scale (Figure 5.3). Indicators assessing the extension of spatially-continuous, compact and high-density residential settlements (1110 and 1121), with a dense infrastructure network (1222 and 1223), green urban areas (1410) and high population density were correlated positively with land consumption. The overall city rate of land consumption was negatively correlated with mean patch size (landscape-level), LUZ size and UK cities. These results indicate that the highest rates of land consumption were observed in the largest and densest metropolitan regions; conversely, small metropolitan areas with less fragmented landscape experienced the lowest rate of land consumption in the sample. The step-wise regression model identifying the variables most relevant in the spatial variation of land consumption rate in the European cities (Table 5.3) indicate that LUZs with a landscape dominated by compact residential settlements (0.36) and agricultural areas (0.18) and with high population density (0.29) and per-capita income (0.24) experienced the highest rate of land consumption. Central Europe and UK cities were experienced a systematically low rate of land consumption compared with the rest of the sample. Small cities mainly situated in Eastern Europe showed regression's residuals > 1. Some small and medium-size cities in Eastern, Central and Southern Europe showed regression's residuals < -1 (Figure 5.4).

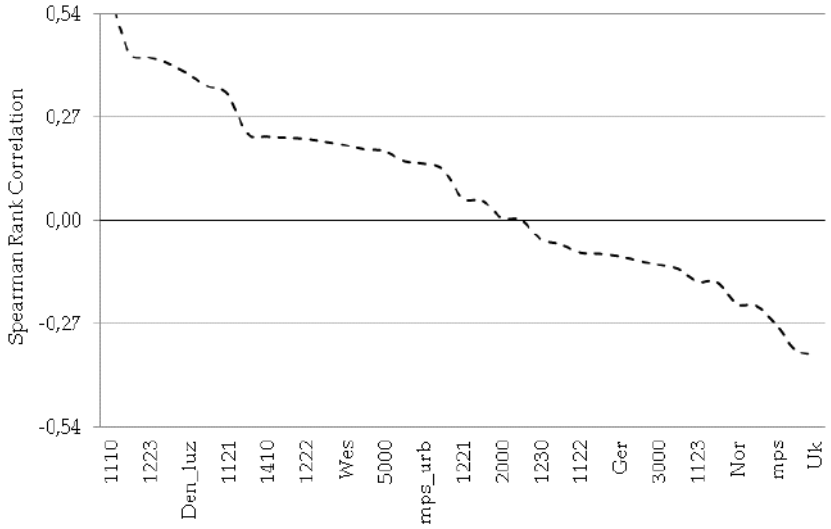


Figure 5.3. Non-parametric Spearman pair-wise correlations between developed land (%) and selected socioeconomic indicators with Significant ($p < 0.05$) indicators with positive coefficients: 1110, 1330, 1223, 1210, DLU, 1340, 1121; negative coefficients: MPS, SUP, UK.

Table 5.3. Results of a linear step-wise multiple regression with developed land (%) as dependent variable and selected socioeconomic indicators as predictors.

Variable	B coefficient	Std. Error	t_{147}	p-level
Adj-R^2 = 0.48; $F_{(7,147)}$ = 21.4, $p < 0.001$				
1110	0.357	0.084	4.244	0.000
GER	-0.154	0.067	-2.302	0.023
UK	-0.288	0.078	-3.711	0.000
DLU	0.289	0.089	3.240	0.001
2000	0.183	0.062	2.934	0.004
EAS	0.337	0.097	3.467	0.001
ILU	0.240	0.088	2.716	0.007

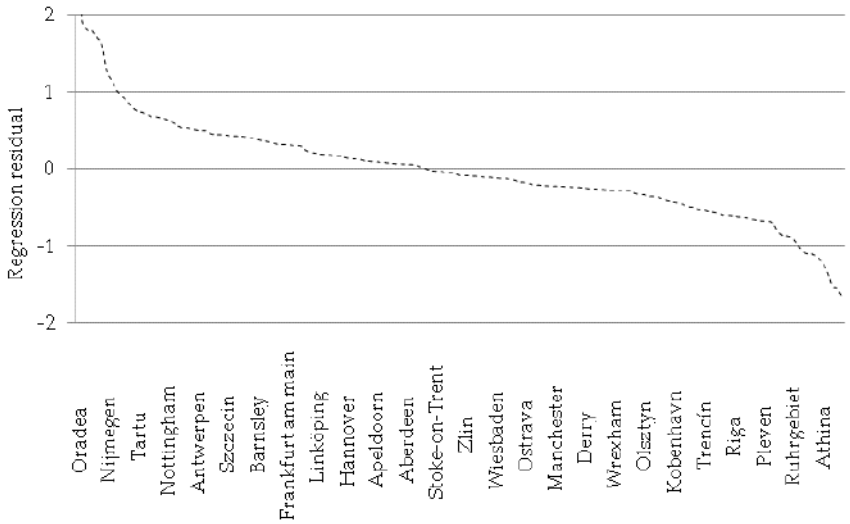


Figure 5.4. Standardized residuals of the step-wise multiple regression model presented in Table 5.3*, with residuals > 1: Oradea, Alba Iulia, Arad, Jastrzebie-Zdrój, Usti Nad Labem, Cluj-Napoca, Nijmegen, Toulouse, Kaunas; residuals < 1: Calarasi, Koszalin, Radom, Valletta, Athens, Braila, Monchengladbach, Giurgiu, Kalisz.

Land-use transformations are influenced by numerous socioeconomic forces (Lambin and Meyfroidt, 2010). In past decades, areas close to compact cities were the most exposed to development pressures, reflecting a high consumption of fringe land. Since World War II, European urban areas expanded by 78%, while their population increased only by 33% (EEA, 2006). These modifications have shaped structure and functions of peri-urban landscapes.

The present study identifies metropolitan profiles experiencing different development trends in 155 European cities (e.g. Kasanko et al., 2006; Lauf et al., 2016; Russo et al, 2017). Empirical results indicated how different forms of urban expansion influenced distinctively land-use changes and land consumption rates according to place-specific factors (Salvati and Gargiulo Morelli, 2014; Oueslati, et al., 2015; Salvati and Carlucci, 2016). Since urbanization has been one of the most pervasive drivers of land-use change, identifying pertinent socioeconomic factors is key to understand land exploitation processes and design effective strategies of urban containment (Zitti et al., 2015; Solon, 2009; Grekousis et al., 2013). Defining socioeconomic contexts resulting from different forms of urban expansion also improves reliability and precision of land-use scenarios (Weilenmann et al., 2017). Transformation of natural land into urban areas, especially low-density settlements, generates on-site and off-site negative impacts (landscape fragmentation, biodiversity loss and reduced environmental quality) reflecting variable institutional quality and effectiveness of policy instruments. This context is in turn shaped by level of socioeconomic development and political freedom and stakeholder's participation to urban planning.

Based on these assumptions, the analysis done considered together socioeconomic and territorial indicators affecting land consumption patterns. Empirical results outlined the considerable variability in land consumption patterns and local socioeconomic contexts (Zitti et al., 2015). Exploratory data analysis highlighted intrinsic characteristics of metropolitan regions by means of key interpretative targets, including territorial and socioeconomic gradient that influence urban expansion. Although a high level of land consumption was detected in various European regions (Eastern, Western and Southern countries), the underlying socioeconomic context was demonstrated to be relatively divergent. Recent processes of land consumption in Eastern Europe were associated to continuous urban growth in medium-large, high-density cities characterized by a compact inner city with declining population. These cities are experiencing a demographic 'shrinkage', with potential impact on socio-spatial structures and concentration (or dispersion) of upper economic functions. In Southern Europe, land consumption was primarily associated with medium- and low-density urban expansion into fringe cropland (La Rosa and Privitera, 2013). This phenomenon was observed in many cities irrespective of demographic size and economic power. Land consumption is a more fragmented and spatially-variable phenomenon in Western European cities, being dependent on mixed socioeconomic forces typical of urbanization processes in both Eastern and Southern countries.

Central-Eastern countries present distinct urbanization paths from the rest of Europe, resulting in specific structure and composition of peri-urban landscapes (Palang et al., 2006). The traditional form of Eastern cities appeared to be compact and dense. Although a land-saving structure, recent urban expansion consumed a considerable amount of green land because of clear territorial transformations. At the same time, dispersed urban expansion was tightly controlled since housing shortage led local authorities to favor high-density social housing developments at the expense of low-density private dwellings. Moreover, the analysis confirmed that, although experiencing an

increase in per-capita disposable in recent years, Eastern cities maintained lower average levels of personal income than the rest of Europe (Couch et al., 2007).

In addition to Eastern cities, urbanization of Mediterranean regions played a critical role in Europe consuming a large amount of green land (Catalán et al., 2008; Salvati and Carlucci, 2014). For a long, Mediterranean landscapes have preserved an extensive agricultural heritage which, in recent times, has been fragmented and degraded because of increasingly dispersed and spatially-discontinuous urbanization around major cities. In these contexts, the characteristic socio-spatial features derived from a transforming population structure, a new land-use structure and uneven changes in housing and job local markets. The progressive transformation of rural areas into mixed peri-urban landscapes was stimulated by unregulated planning, poor zoning instruments and lack of controls, resulting sometimes in informal settlements (Giannakourou, 2005; Salvati and Carlucci, 2016; Zambon et al., 2017; Leontidou, 1995; Gospodini 2006; Souliotis, 2013; Zitti et al., 2015; Salvati, 2016).

The diversity between European countries certainly derives from their history, tradition and consistency of the territorial management tools. The evolving planning culture influenced urban trends among European regions, starting from western planning traditions (as in United Kingdom, The Netherlands and Denmark) to new planning systems in Eastern Europe (e.g. Poland) (Hall and Hay, 1980; Di Feliciantonio and Salvati, 2015).

Despite assuming distinct characteristics, cities in UK, Central and Northern European countries faced with a low rate of land consumption during 2006-2012. While being sometimes characterized by a sprawled urban structure, some of these cities have adopted experienced effective control mechanisms as a response to uncontained urbanization and residential sprawl (Halleux et al., 2012).

5.2.3. Policies and strategies against land consumption

Based on these premises, more effective policies at both European, country and local scale are increasingly required to reduce land consumption in growing (and even shrinking) regions. Although urban containment strategies are well-known planning tools for managing urban sprawl, their indirect impact on land consumption should be better investigated (Gennaio et al., 2009). These strategies are aimed at restricting urban development to specific areas where a high housing density is permitted. Land consumption indicators contribute to recognize local areas where urban containment strategies are successful (Hasse and Lathrop, 2003). These indicators provide also an important knowledge base to design practical measures reducing sprawl (Colantoni et al., 2016). To be effective, policy implementation in diverging socioeconomic conditions may consider practical measures which support local governance and adaptive management. While implementing effective measures for urban sprawl is an essential response to land consumption, modulation of country and regional directives to the intimate characteristics of local contexts has been demonstrated to be crucial in a more general strategy of urban containment (Pendall, 1999). The spatially-varying socioeconomic contexts underlying land consumption phenomena across Europe may justify an approach of this kind (Ferrara et al., 2014; Pauleit et al, 2010).

In this sense, strategies that re-direct urban expansion toward a self-contained development path, resulting in continuous and dense forms, are effective only in specific contexts, as emerged in the case of the most compact Eastern cities, showing the highest rate of land consumption in Europe. A self-contained development could be accompanied by socio-demographic policies addressing

wealthier, less-polarized and spatially-accessible contexts, which are characterized by a mixed urban landscape and a diversified natural landscape surrounding central cities.

However, the outcomes of spatial planning policies are not simple to evaluate (Van Der Burg and Dieleman, 2004). Geo-spatial databases assessing land-use change over enough long-time periods provide the necessary information to evaluate how land consumption (i) influences urban structure and European peri-urban landscapes (and vice versa) and (ii) is intimately related to the (evolving) socioeconomic context at local scale (Munafò et al., 2010). With advancements in environmental monitoring schemes and land management approaches, a joining framework for permanent evaluation of land consumption driven by different types of urbanization is requested to assess patterns and processes of urban expansion in larger regions and at higher spatial resolution, estimating consequences to rural ecosystems.

5.3. Land quality, sustainable development and environmental degradation

Sustainable agriculture has been assumed to perform a pivotal role in the animal biodiversity and plant conservation (e.g. Weissteiner et al., 2011). Traditional agricultural systems contribute to eco-compatible uses of rural land, preserving soil quality and ensuring long-term ecosystem functioning (Siciliano, 2009). Rural landscapes with high natural value have experienced both crop intensification and land abandonment, with changes of land-use and loss of usual practices and cultural heritage preserved by local communities (Agnoletti, 2007; Navarro and Pereira, 2012; Salvati and Zitti, 2007). The main socioeconomic consequences of crop intensification and land abandonment have been identified at the local scale, offering original approaches in the analysis of environmental degradation, land management practices and application of existing strategies (Corbelle-Rico et al., 2012; EEA, 2005; Helming et al., 2011; Kosmas et al., 1999, 2015; Recatala et al., 2002; Strijker, 2005). The improvement of the research on adaptive capacity of agricultural districts allows to understand better complex socio-ecological systems and to clarify the effectiveness of both formal and informal replies to external shocks (Emadodin et al., 2012; Ibarrarà et al., 2010; Watson et al., 1998).

Cited article

Zambon, I., Colantoni, A., Carlucci, M., Morrow, N., Sateriano, A., Salvati, L. (2017). Land Quality, Sustainable Development And Environmental Degradation In Agricultural Districts: A Computational Approach Based On Entropy Indexes. Environmental Impact Assessment Review 64, 37-46.

Biophysical processes have continuously shaped the socio-environmental profile of rural landscapes and local communities (Salvati et al., 2015). Together with climate aridity, land-use changes and increased human pressure, Land Degradation (LD), as a global problem with negative implications for both humans and nature, has recently expanded in both affluent and emerging countries (European Environment Agency, 1998; Graaff and Epping, 1999; Hermann and Hutchinson, 2005; Perminova et al., 2016; Santos and Cabral, 2003). Increased competition for land resulted in a deterioration of soil quality with relevant decrease of land productivity, biodiversity and ecosystem services (Emadodin and Bork, 2011; Emadodin et al., 2009; Imeson, 2012; Zdruli, 2014; Zinck et al., 2004). Soil degradation, together with the increased land sensitivity to desertification, is a potential result of the combination of biophysical conditions such as arid climate, low vegetation cover, poor soils and water scarcity (Bielsa et al., 2005; Feoli et al., 2003; Ferrara et al., 2014; Garcia Latorre et al., 2001; Geri et al., 2010; Hernández et al., 2015; Kosmas et al., 2000a; Lavado Contador et al., 2009; Moonen et al., 2002; Preiss et al., 1997; Salvati et al., 2011; Saura et al., 2011a, 2011b).

Economically-disadvantaged and marginal rural contexts in dry environmental conditions are typically found in Mediterranean Europe (Salvati and Carlucci, 2011). In those contexts, having an extensive history of human settlement and land-use (Blondel, 2006; Hernández et al., 2015), socioeconomic factors mixed with spatially-variable biophysical conditions, influencing socio-ecological local systems and eliciting complex responses to natural resource degradation (e.g. Berkes and Folke, 1998; Kurttila, 2001; Salvati et al., 2015). In these conditions, land degradation has been demonstrated to be particularly intense, being a consequence of land abandonment, soil erosion, rural poverty and land value loss (Salvati and Zitti, 2009a, 2009b). Land degradation is intimately related to overgrazing, wildfires, unsustainable exploitation of water and soil resources and environmental pollution, e.g. caused by pesticides and herbicides (Beaufoy, 2001; Salvati and Carlucci, 2011; Santos and Cabral, 2003). Expansion of degraded areas has increasingly involved

traditional agricultural systems, determining a progressive depletion of fertile land, loss of biological and economic productivity, soil erosion, habitat fragmentation and reduced ecosystem services (Brandt et al., 2003; Costantini et al., 2009; Gisladottir and Stocking, 2005; Montanarella, 2007; Salvati and Zitti, 2008, 2009a; Tanrivermis, 2003). Depletion of high-quality cropland has been also associated to urban expansion in flat and accessible rural districts (Recatalá et al., 2000). A total of 9000 km^2 of rural land have been transformed for urban functions in the 1990s (EEA and JRC, 2010), growing steadily between 2000 and 2006 (Recatalá and Sacristán, 2014). Population growth in urban areas has, in turn, stimulated an increased food demand that may lead to crop intensification (Emadodin et al., 2012; Gardi et al., 2014), which often aggravates LD (Bakr et al., 2012; Kangalawe et al., 2010; UNCCD, 2002; Worldwatch Institute, 1998).

Multifaceted relationships between land sensitivity to degradation and basic drivers of landscape transformations have been observed in Mediterranean environments, involving differentiated socioeconomic and biophysical factors (Lal, 2001). An effective assessment of LD requires a comprehensive investigation of the progress of socio-ecological systems, over time and space (Thornes, 2004). Despite extensive research focusing on Mediterranean environments (Basso et al., 2000; Benabderrahmane and Chenchouni, 2010; Brandt, 2005; Kosmas et al., 1999, 2000a, 2000b), relatively few studies were aimed at identifying vulnerable areas over large regions (Lavado Contador et al., 2009; Leman et al., 2016; Symeonakis et al., 2014), investigating their spatial dynamics over relatively long time periods (Basso et al., 2012). The Mediterranean Desertification and Land Use (MEDALUS) approach identifies Environmentally Sensitive Areas (ESAs) to LD through a multi-factor approach incorporating vegetation, climate, land and soil management indicators (Kosmas et al., 1999), being ESA a simple, robust and adaptable approach to new information (Brandt et al., 2003; Ferrara et al., 2012; Kosmas et al., 2003). Using a complex index called the ESAI, the land sensitivity degree and the effectiveness of the relative policies combating desertification, can be evaluated following a detailed land evaluation system based on multiple criteria and thresholds (Salvati and Carlucci, 2010).

Agricultural districts, intended as potentially vulnerable socio-ecological contexts to land degradation are suitable spatial units to assess the impact of (regional and local) environmental policies (Salvati and Zitti, 2008). Salvati and Carlucci (2013) studied the latent relationship between productive and ecological attributes of Italian agricultural districts and land sensitivity to degradation. Between 1960 and 2010, the intense growth of sensitive areas to degradation in Italy is the result of an increased human pressure on agricultural soils, coupled with climate aridity and landscape fragmentation (Salvati and Bajocco, 2011; Salvati and Carlucci, 2013). Land Degradation determined serious consequences to traditional cropping systems in the Mediterranean rural landscapes (Bajocco et al., 2012). Decreased crop productivity (Conacher and Sala, 1998; Ibanez et al., 2008; Salvati, 2010; Salvati and Carlucci, 2013) or increased poverty in rural populations (Lorent et al., 2008) are typical outcomes of land degradation (Basso et al., 2000). Nonetheless, recent studies demonstrate that LD can be controlled through adequate land management measures (Bakr et al., 2012).

Based on these assumptions, the present study provides an in-depth investigation of changes in biophysical and socioeconomic conditions of agricultural districts over time with the objective to assess local-scale spatial diversification in the degree of land susceptibility to degradation, taken as a proxy of desertification risk. Mediterranean rural areas are characterized by an evident diversity

in agricultural systems (Salvati and Bajocco, 2011). Despite all European countries offer typical agricultural productions, the majority high-quality products are found in Mediterranean countries (Jongman, 2002). Socioeconomic transformations, due to processes of landscape, may reflect in a higher level of homogeneity or heterogeneity in the level of land sensitivity to degradation, representing a possible threat to biodiversity resources (Jongman, 2002).

Assumed that southern Europe rural landscapes have experienced both homogenization and fragmentations processes (Jongman, 2002), an in-depth investigation on the changing distribution of the ESA index, over time and space through the notions of diversification and heterogeneity, may contribute to foresee sensitive contexts to LD. In this sense, Italy represents an attractive case of study, given its complex spatial distribution of areas sensitive to degradation, resulting from the joint action of multiple geographical gradients (Salvati, 2010; Salvati and Zitti, 2008). Being classified as a sensitive country to desertification according to United Nation Convention to Combat Drought and Desertification (UNCCD) Annex IV, Italy has experienced intense evolution of LD, especially in the Southern driest areas (Salvati and Zitti, 2008).

The increase over time in the level of vulnerability with spatially heterogeneous land-use structures, affects specific uses of land including mixed urban-rural mosaics (Ferrara et al., 2015; Salvati, 2013). Vegetation patchiness at a very local scale is an early-warning indicator of desertification risk (Kefi et al., 2007). Being aware that arid ecosystems are ones of most sensitive ecosystems to climate change (Schroter et al., 2005), diversity and evenness in land-use structures - reflecting homogeneity (or heterogeneity) in the level of sensitivity to land degradation - were proposed as proxies of desertification risk at the district scale, when considering homogeneous socioeconomic local systems. Based on evidences provided by Kefi et al. (2007) at the spatial scale of land patch, a more heterogeneous distribution of sensitive land in agricultural districts is hypothesized to be associated with higher exposure to land degradation and increasing rates of growth in the level of land sensitivity to degradation, possibly reducing the effectiveness of regional policies against desertification (Salvati and Carlucci, 2011, 2014). Spatial heterogeneity in the ESAI has frequently indicated the occurrence of degraded areas that may act as hotspots for future degradation processes (Bajocco et al., 2015).

Based on these premises, the study assumes the local districts defined by the Italian National Institute of Statistics (ISTAT, 1958) and partitioning Italy into homogeneous agricultural areas as the spatial unit of analysis. Agricultural districts are homogeneous socio-environmental systems that identify clusters of municipalities with similar ecological and agronomic characteristics (Recanatesi et al., 2015). Evaluating latent relationships among the average level of land sensitivity to degradation and its spatial heterogeneity at the agricultural district scale provides interesting information for compiling a regional strategy for the mitigation of desertification risk in European Mediterranean countries. Pielou's evenness and Shannon's diversity indexes were used to estimate local-scale diversification in the ESA index at the spatial scale of agricultural districts over the last 50 years (1960-2010) in Italy. The study hypothesizes that a higher level of diversification in the spatial distribution of basic ESAI classes was associated with increased rates of change in the level of land sensitivity over time. Homogeneous agricultural districts are supposed to be less exposed to desertification risk, being possibly more resilient to LD (Thornes, 2004).

5.3.1. Environmental degradation in Italian agricultural districts

The area considered includes the whole Italian territory. Italian land is characterized by undulated topography (23% lowlands, 42% uplands, 35% mountains) and multifaceted rural landscapes with conventional crop systems shaped by spatially-varying environmental conditions. A total of 773 agricultural districts were considered as elementary spatial units of analysis, excluding some smaller islands (e.g. Ponza, Capri, Giglio, Ischia, Procida, Tremiti). Agricultural districts were delineated by the ISTAT (2006) considering biophysical (e.g. topography, climate and soil) and socioeconomic variables (e.g. crop system, land value and human settlements).

5.3.2. The ESA approaches

We considered the notion of 'land sensitivity to degradation' proposed by Kosmas et al. (1999) in the outline of the MEditerranean Desertification and Land USe (MEDALUS) project. 'A state of a local system' is primarily subject to (i) quality of natural capital (soil, water, vegetation), (ii) climate regime and (iii) anthropogenic pressures (Kosmas et al., 2000a, 2000b). The MEDALUS project introduced a comprehensive valuation of changes over time considering four quality dimensions (climate, soil, vegetation and land management) as fundamental factors associated to LD along the Mediterranean basin (e.g. Montanarella, 2007; Sivakumar, 2007). Such procedure adopted refers to the Environmentally Sensitive Area (ESA) approach and includes 14 elementary variables, elaborated through basic statistical tools and spatial investigation with the purpose of developing a combined index of land sensitivity, called the ESAI. Four elementary variables were correspondingly measured in the estimation of soil quality (soil depth, texture, parent material, slope) and vegetation quality (protection against soil erosion and drought, wildfire risk, plant cover); three elementary variables were respectively used to evaluate climate quality (precipitation, aridity, aspect) and land management quality (demographic growth, population density, land-use intensity).

The ESA framework identifies four quality indicators: Climate Quality Index (CQI); Soil Quality Index (SQI); Vegetation Quality Index (VQI); and land Management Quality Index (MQI). These indicators were calculated as the geometric mean of the sensitivity values of every elementary variable (Salvati el al., 2016). Quality indicators assume a value ranging between 1 (lowest sensitivity to degradation) and 2 (the highest sensitivity to degradation). Since the ESAI has been computed as the geometric mean of the four quality indicators with neutral weighting, the land classification adopted was structured in: (i) non-affected areas or very low sensitive areas to LD (ESAI < 1.3); (ii) low sensitivity areas to LD (1.3 < ESAI < 1.4); (iii) areas with medium sensitivity to LD (1.4 < ESAI < 1.5); and (iv) highly sensitive areas to LD (ESAI > 1.5). The ESAI classification system is aimed at identifying critical areas that need specific mitigation actions against LD (Kosmas et al., 1999).

The ESA approach is very used as procedure to categorize land giving to the degree of sensitivity to degradation (Basso et al., 2000; Salvati and Bajocco, 2011; Salvati and Zitti, 2009a, 2009b). The principal benefits of the ESA are (i) elasticity in the utilization of input variables and (ii) easiness of land classification system which relies on the intrinsic degree of sensitivity to selected biophysical and socioeconomic conditions (Ferrara et al., 2012). The results obtained from the ESA model have been widely validated in Mediterranean European contexts (Basso et al., 2000; Kosmas et al., 1999; Salvati and Zitti, 2008). The ESAI represents a proxy of LD, showing important correlations with several soil degradation indicators (Lavado Contador et al., 2009). The variables considered were

derived from consistent, referenced and updatable data sources (Salvati et al., 2012). However, since LD means a multifaceted phenomenon given its acting factors (Hill et al., 2008), some of the latter could be undervalued in the ESA approach (Montanarella, 2007). In this sense, Salvati et al. (2012) have demonstrated that using a larger and independent set of LD indicators leads to the identification of a spatial organization of sensitive land to degradation coherent with the ESAI (Salvati et al., 2012). Multiple correlations between elementary ESA variables and an exhaustive set of LD indicators offered similar outcomes to what was found from the utilization of the standard ESA scheme (Salvati and Zitti, 2009b).

A total of 14 context indicators based on the ESA scheme (Table 5.4) were calculated for each study year (1960, 1990, 2000, 2010). Separate figures of averages and coefficients of variation for each quality indicator (CQI, SQI, VQI, MQI) and the ESAI were estimated at each district by means of the 'zonal statistics' tool during the elaboration with the ArcGIS software (Salvati and Zitti, 2008). The percent share of land defined as 'fragile' and 'critical' (respectively 1.225 < ESAI < 1.375 and ESAI > 1.375) in total landscape and the minimum and maximum ESAI value in each agricultural district were finally calculated.

Table 5.4. Variables considered and the associated measurement scale by Italian agricultural district.

Acronym	Variable name	Measurement scale
H	Shannon's diversity index	Score ranging from 0 to ∞
J	Pielou's evenness index	Score ranging from 0 to 1
ESAI	Environmentally Sensitive Area Index	Score ranging from 1 to 2
ESAICV	Coefficient of variation in the ESAI score	Percentage
CQI	Average Climate Quality Index	Score ranging from 1 to 2
CQICV	Coefficient of variation in the CQI score	Percentage
SQI	Average Soil Quality Index	Score ranging from 1 to 2
SQICV	Coefficient of variation in the SQI score	Percentage
VQI	Average Vegetation Quality Index	Score ranging from 1 to 2
VQICV	Coefficient of variation in the VQI score	Percentage
MQI	Average land Management Quality Index	Score ranging from 1 to 2
MQICV	Coefficient of variation in the MQI score	Percentage
FRAG	Surface land defined as 'fragile' (1.225 < ESAI < 1.375)	Percent area in total landscape
CRIT	Surface land defined as 'critical' (ESAI > 1.375)	Percent area in total landscape
MIN	Minimum value of the ESAI	Score ranging from 1 to 2
MAX	Maximum value of the ESAI	Score ranging from 1 to 2

5.3.3. Entropy indicators

Two entropy indicators were used to assess spatial diversification and heterogeneity in the spatial distribution of the ESAI scores at the agricultural district scale in Italy: Shannon's diversity (H') and Pielou's evenness (J) indexes. The H' index (Shannon and Weaver, 1949) was calculated as:

$$H' = - \sum_{i}^{n} [\, pi \log pi \,]$$

where n is the number of ESAI score classes and pi is the proportion of surface area of each i-th class. This index estimates the average uncertainty in a finite community, ranging from 0 to highly positive values and evaluating the level of spatial diversification of the ESAI for each agricultural district. By dividing H' by the Hmax value depending on the number of ESAI classes in every

district, J index assesses evenness of the ESAI values (Pielou, 1966) in a scale ranging between 0 and 1, respectively from low to high evenness:

$$J = H' / Hmax$$

where Hmax is the logarithm regarding the number of classes with surface area > 0 (Ludwig and Reynolds, 1988). Following Li and Sun (2000), changes in the ESAI H' index may indicate landscape processes of interest for desertification assessment; changes in the J index may also report the variable distribution of sensitive land to degradation and its potential growth at the landscape scale. Maps of H' and J indexes were prepared by means of the ArcGIS software (ESRI Inc., Redwoods, USA).

5.3.4. Evaluating the spatial structure of the ESAI in Italy

An ancillary set of indicators were considered to assess the basic characteristics of any given district: (i) Sou (classifying districts on the base of the latitude gradient: '0' indicates northern-central districts, while '1' indicates southern districts in Italy); (ii-iii) two indicators classifying districts on the base of elevation: Low ('0' indicates hilly or mountainous districts, '1' indicates flat districts) and Mou ('0' indicates mountainous districts, '1' indicates flat or hilly districts); (iv) Sea ('0' indicates inland districts, '1' indicates coastal districts); (v) Area (indicating the surface area of each agricultural district, km^2).

The analysis framework evaluated changes in the spatial relationship between entropy indicators (H', J) in the spatial distribution of the ESAI, standard ESA variables and contextual indicators. Pair-wise correlations between each of the selected ESAI variables and each entropy indicator were assessed using Spearman non-parametric analysis testing for significant coefficients at $p < 0.05$ after Bonferroni's correction for multiple comparisons. Also a Principal Component Analysis (PCA) was run on the dataset including entropy indicators and standard ESA variables distinctly for two time points (1960 and 2010) with the aim at evaluating (i) the role of each ESA variable in the overall level of land sensitivity to degradation in each agricultural district and (ii) latent, multiple relationships between diversification in the ESAI spatial distribution and the level of land sensitivity to degradation. Variables with loading > |0.5| were considered significantly associated with a given component. The Bartlett's test of sphericity and Kaiser Meyer-Olkin measure of sampling adequacy were used to evaluate reliability of the factor model, verifying respectively (i) if partial correlations between variables are small and (ii) if the correlation matrix is an identity matrix (Salvati and Zitti, 2009a). Finally, a hierarchical clustering was performed for 1960 and 2010 on the same dataset submitted to PCA, with the aim of classifying agricultural districts into homogeneous groups by applying a computation strategy, based on Euclidean distances and Ward's amalgamation rule. Clustering determined which indicators have contributed to the definition of relevant spatial groups characterized by specific environmental conditions and level of diversification in the spatial distribution of the ESAI.

Results of this study outline the main changes in basic environmental conditions predisposing land to degradation at the territorial scale of Italian agricultural districts. In 1960, ESAs were primarily situated in Southern Italy, except for few districts including some metropolitan regions in central and northern Italy (Figure 5.5). A huge intensification in the average ESAI score between 1960 and 2010 was observed in the above-mentioned areas and, more generally, along the Adriatic Sea coast and the Po valley. A descriptive analysis of Shannon's diversity (H') and Pielou's evenness

(J) indexes, based on the spatial distribution of ESAI scores at the scale of agricultural districts, provided similar results. The spatial distribution of H' index values outlines that southern Italy and Apennine districts display the most heterogeneous environmental conditions shaping land sensitivity to degradation. An increasing level of diversification in the ESAI was observed throughout Italy, in contrast with the dominant spatial pattern found in lowland areas, such as the Po valley. These areas support high-input agricultural systems characterized by crop intensification and homogeneous environmental conditions (low values of H' and J indexes) leading to medium-high ESAI scores. A medium-high value of J index was attributed to many rural districts in upland and mountainous regions, being characterized by a diversified landscape with crop mosaic, agro-forest land and communities established.

Results of a non-parametric Spearman rank correlation analysis corroborate this preliminary finding (Table 5.5). The J index varied significantly along the latitude gradient (1990, 2000) being higher in northern districts than elsewhere in Italy. At the beginning of the study period, both H' and J indexes increased with elevation, VQI, average ESAI score and the percent area of 'fragile' land in total landscape. Fifty years later, H' and J correlated positively with coefficients of variation of both VQI and ESAI. The SQI coefficient of variation was stably and positively correlated with the H' index for both 1960 and 2010. In most recent decades, spatial heterogeneity in the ESAI score increased with percent area of 'critical' land and the maximum ESAI score observed in each district.

Table 5.5. Pair-wise Spearman rank correlation coefficients between selected environmental variables for each homogeneous agricultural district in Italy and two indicators of entropy in the spatial distribution of the ESAI (H': Shannon's diversity index, J: Pielou's evenness index). Only significant coefficients tested at $p < 0.05$ ($n = 762$) after Bonferroni's correction for multiple comparisons were shown).

Variable	Shannon H' diversity index				Pielou J evenness index			
	1960	1990	2000	2010	1960	1990	2000	2010
ESAI	0.45							
ESAICV	0.85	0.91	0.92	0.92	0.58	0.69	0.69	0.75
SQICV	0.32	0.36	0.34	0.33				
VQI	0.55				0.37			
VQICV	0.65	0.74	0.75	0.75	0.47	0.59	0.60	0.65
FRAG	0.60				0.39			
CRIT	0.39	0.30	0.32					
MAX	0.55	0.36	0.37					
Sou						0.30	0.34	
Low		-0.44	-0.44	-0.45		-0.30	-0.31	-0.38

5.3.5. Profiling agricultural districts based on entropy indexes

Figure 5.1 illustrates the most relevant change over time in the selected entropy indicators assessing spatial diversification of the ESAI scores at the rural district scale. In 1960, most agricultural districts with medium-high H' index were situated in Southern Italy and in the western side of central Italy. During 1960-2010, the H' index increased homogeneously throughout the country and an analogous pattern was detected for the spatial distribution of the J index, with the highest rates of change being recorded in Sardinia and Sicily. In this sense, both H' and J indexes are spatially-distributed following a latitude gradient with the lowest values of both indexes concentrated in the Po valley.

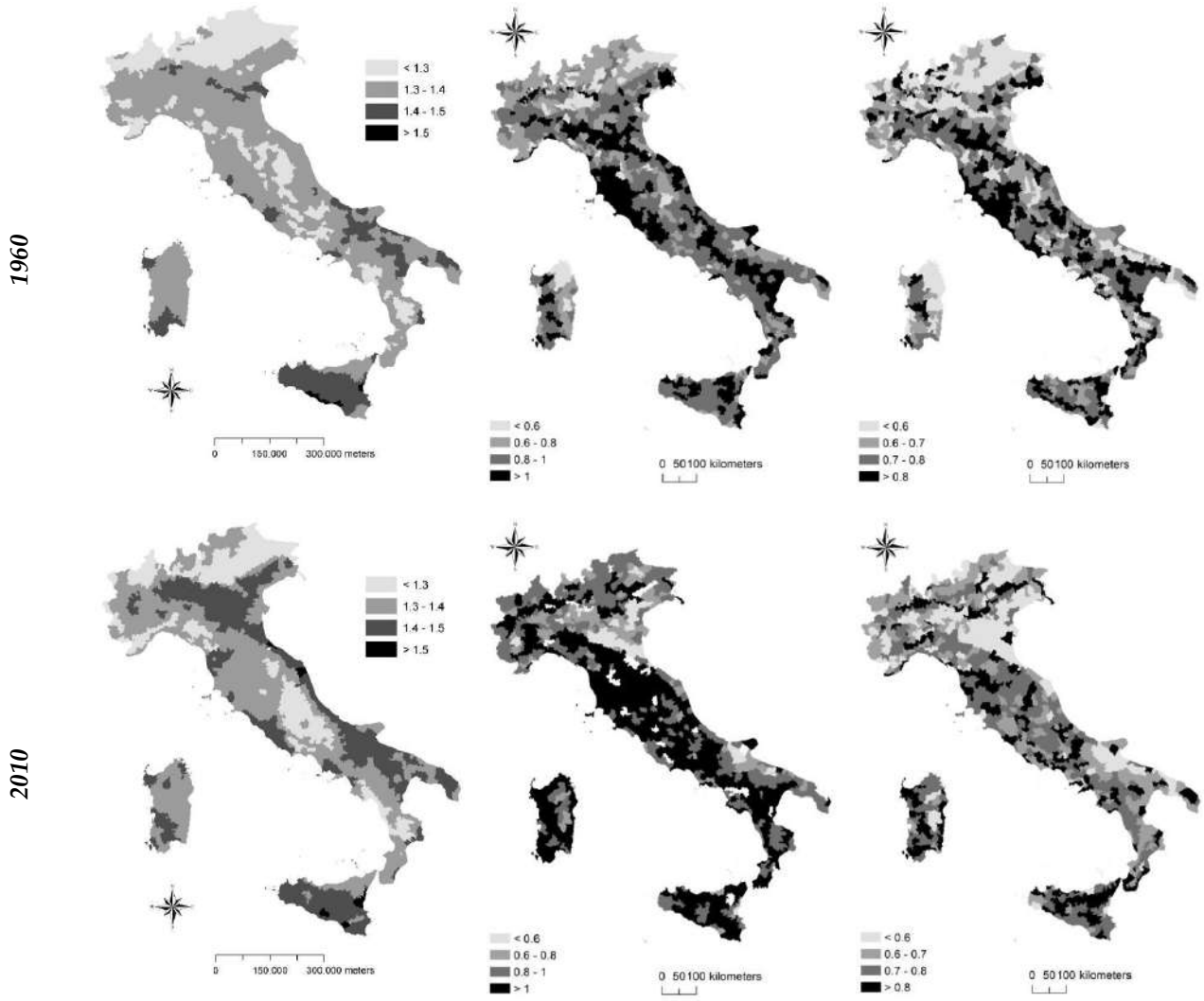


Figure 5.5. Spatial distribution of the average ESAI score (left), Shannon's Diversity Index (H, middle) and Pielou's Evenness Index (J, right) by year and agricultural district.

Spearman analysis (Table 5.6) indicated that diversification in the spatial distribution of the ESAI was the highest in districts experiencing a rapid increase in the ESAI score in the earlier decades of this study (1960-1990, 1990-2000). The reverse pattern was detected in the last decade, with negative variations in the level regarding the land sensitivity to degradation being analyzed in districts with high diversification and evenness in the spatial distribution of the ESAI score. Table 5.6. Pair-wise Spearman rank correlation coefficients between H' or J indexes at the beginning of each time interval and percent annual rate of growth in the ESAI at each time interval and agricultural district (significant coefficients tested at *0.001< p < 0.05 or ** p < 0.001 (n = 762) after Bonferroni's correction for multiple comparisons).

Variable	1960-1990	1990-2000	2000-2010
H'	0.14^{**}	0.13^{*}	-0.26^{**}
J	-0.04^{ns}	0.11^{*}	-0.22^{**}

5.3.6. Identifying latent factors influencing the spatial distribution of the ESAI

PCA was run to summarize the environmental variables profiling agricultural districts and to point out the latent relationship with H' and J indexes in the spatial distribution of the ESAI (Table 5.7). PCA removed the partial correlation between variables incorporating significant information in a limited number of independent components resulted as a linear combination of the most significant variables. Referring to 1960, component 1 was negatively associated with H', ESAI, CQI, VQI, FRAG, CRIT, MIN, and MAX. The two entropy indicators (H' and J), ESAICV and VQICV received significant loadings to component 2. Moderate changes in the structure of both components 1 and 2 were observed for 2010. VQI and MQI received negative loadings to component 1; H' and ESAICV received positive loadings. Component 2 had positive loadings for the two entropy indicators and the ESAICV. The changing structure of components 1 and 2 for H' and J indexes outlines the increasing complexity of basic environmental conditions in the Italian agricultural districts along the period of study.

Table 5.7. Results of a PCA applied to variables assessing basic environmental characteristics of the Italian agricultural districts in 1960 (left) and 2010 (right). Variable's loadings > |0.5| were shown.

Variable	1960		2010	
	Component 1	Component 2	Component 1	Component 2
Shannon's diversity	-0.65	0.65	0.58	-0.72
Pielou's evenness		0.54		-0.67
ESAI	-0.92		-0.89	
ESAICV		0.79	0.64	-0.65
CQI	-0.69			-0.55
VQI	-0.78		-0.79	
VQICV		0.70	0.76	
MQI			-0.69	
FRAG	-0.87		-0.86	
CRIT	-0.65		-0.56	-0.54
MIN	-0.70	-0.55	-0.83	
MAX	-0.90		-0.57	-0.73
Expl. Var %	38.3	19.4	38.6	22.6

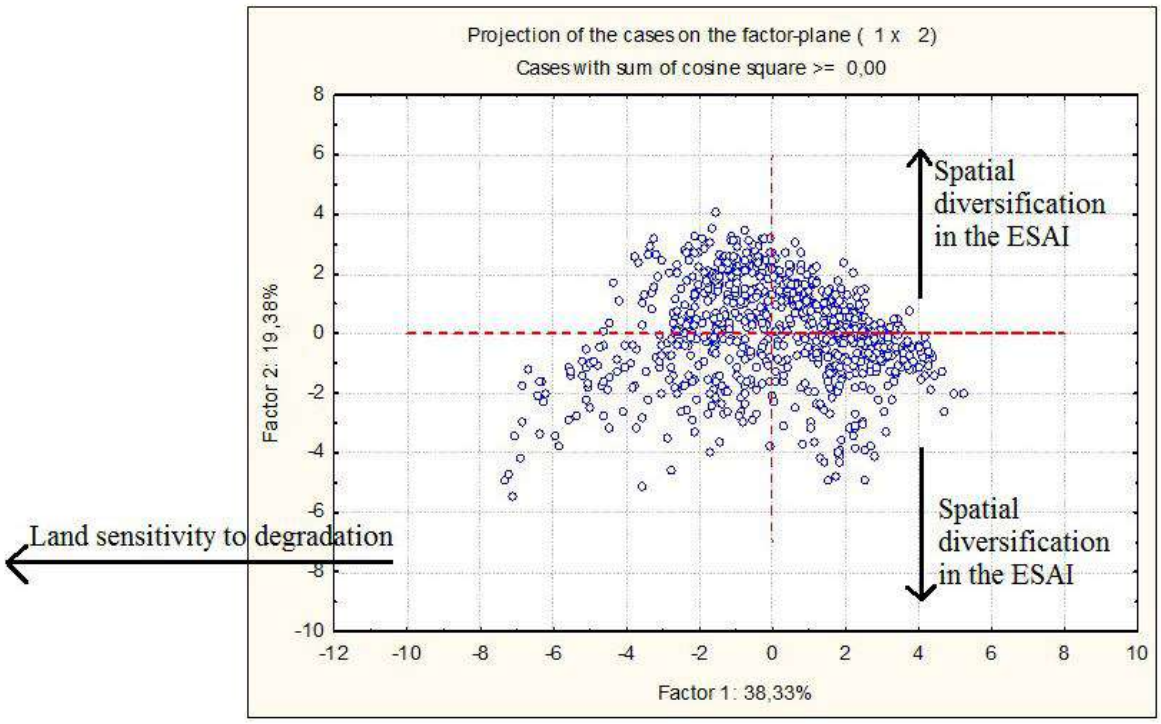
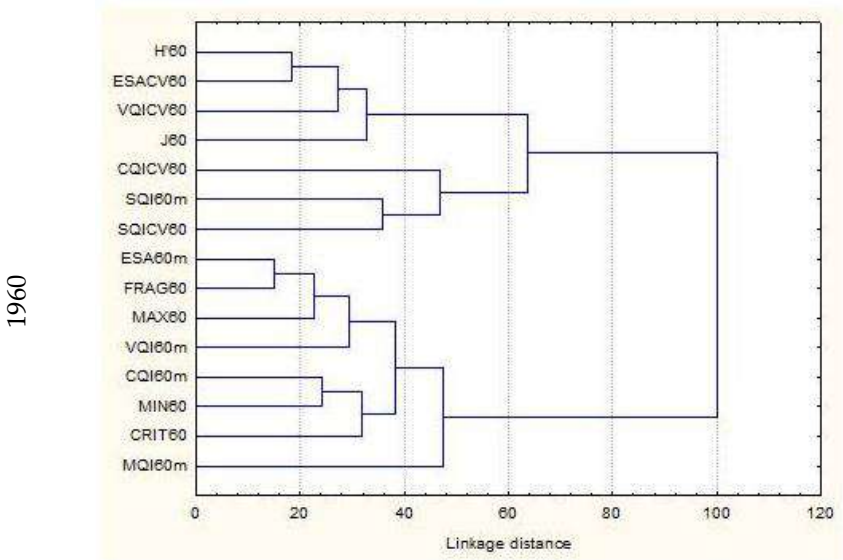


Figure 5.6. Component score plot (circle identifies the agricultural districts more exposed to LD and with the highest diversification in the ESAI in 2010).

5.3.7. Determining coherent spatial patterns

A hierarchical clustering (Figure 5.7) identified correspondences in the spatial distribution of the elementary variables discriminating land with high or low level of sensitivity to degradation. Two homogeneous groups were identified: the first group is composed by two sub-clusters including respectively four variables (the two entropy indicators, ESAICV, VQICV) and three variables (CQICV, SQI, SQICV). Cluster membership was relatively stable over time. The second group was again composed by two sub-clusters: ESAI, FRAG, CQI and MQI clustered together and were clearly separated from CQI, MIN, MAX and CRIT forming a second sub-cluster.



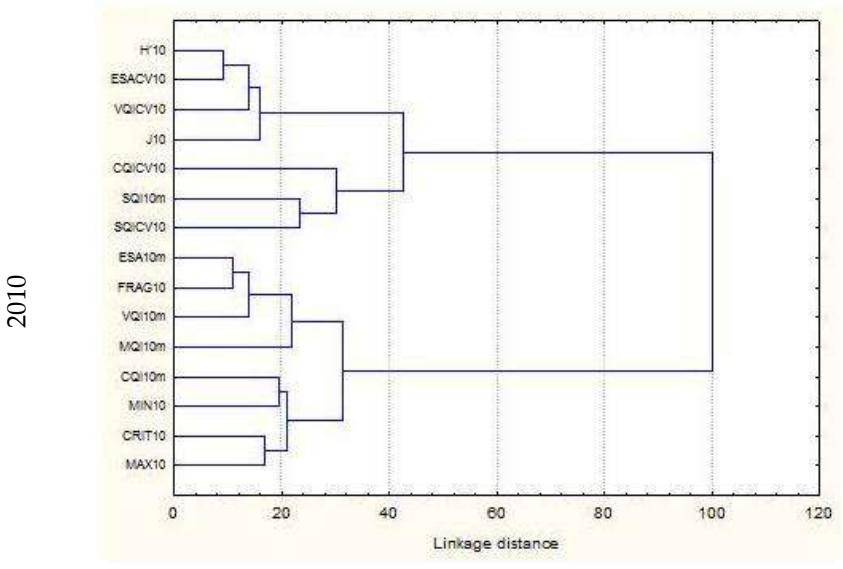


Figure 5.7. Hierarchical Clustering of the selected variables profiling the Italian agricultural districts by year.

5.3.8. Spatial diversification in Italy for land sensitivity to degradation

The approach constitutes a reliable monitoring system that integrates information on the long-term sustainability of rural districts based on a composite index regarding the sensitivity to LD (Feoli et al., 2003). The effective monitoring of soil degradation patterns and desertification risk can use a mixed qualitative and quantitative approach with the intention of describing the evolutionary path of each district (Salvati et al., 2015). According to Bakr et al. (2012), desertification processes should be monitored over time to define more effective sustainable development measures. A high degree of land sensitivity indicates candidate targets for adopting mitigation measures against desertification (Gisladottir and Stocking, 2005). Early-warning desertification indicators, based on diversification in the spatial distribution of the ESAI, are particularly helpful to design strategies specifically adapted to local contexts and place-specific environmental dynamics of change.

Multiple feedbacks, associated with a spatially-heterogeneous distribution of sensitive land to degradation, require dedicated assessment techniques and place-specific mitigation measures (Ferrara et al., 2015). Analysis should consider the specific characteristics of territorial contexts and local communities, possibly identifying distinctive trends in the levels of land sensitivity thanks to the action of diversified environmental factors and socioeconomic drivers of change. Transformation of rural landscapes in Italy reflects a progressive increase of land sensitivity to degradation (Salvati et al., 2016). Such changes have been influenced by multifaceted drivers, emphasizing the intimate relationship between human activities and land resources (Gleick et al., 2002; Khanji, 2016; MEA 2005a, 2005b; UNEP, 1994; WCED-CMED, 1987). According to Hermann and Hutchinson (2005), relevant causes of LD are associated to the spatial-temporal dynamics of four dimensions (climate, vegetation, soil, socioeconomic processes), shaping impacts of land management strategies at local scale (Hermann and Hutchinson, 2005; Salvati, 2014).

The present study proposed the notion of 'spatial diversification' in the level of land sensitivity to degradation in Italian rural districts, with the purpose to define latent hotspots for desertification risk (Recanatesi et al., 2015). Empirical findings indicate that the level of land sensitivity to

degradation is influenced by spatial heterogeneity in the environmental conditions at the base of LD. Agricultural districts with spatially-homogeneous environmental situations were more exposed to LD in recent decades in respect to the time-period immediately following the World War II. Diversification in the spatial distribution of the ESAI has been related with specific territorial contexts characterized by a high degree of land sensitivity. Cropland demonstrated to be particularly prone to environmental conditions leading to LD when the spatial structure of agro-forest districts (e.g. crop mosaic, landscape fragmentation, traditional forestry systems, agricultural practices and typical productions, rural communities) has been compromised (Colantoni et al., 2015). Human-driven LD has been observed in both economically-marginal rural areas of southern Italy and affluent districts of northern Italy with soil and climate conditions getting worse in the last decades (Salvati and Carlucci, 2013). According to Salvati et al. (2015), Mediterranean rural areas are considered as increasingly exposed to desertification risk, due to joint action of climate aridity and socioeconomic pressures (Lorent et al., 2008; Mendelsohn and Dinar, 2003; Olesen and Bindi, 2002; Salvati and Zitti, 2009b). Despite Southern Italy is widely recognized as a risky area (Salvati and Bajocco, 2011), LD sensitivity was advancing rapidly also in central and northern Italy. Following Salvati and Carlucci (2013), the spatial distribution of rural districts sensitive to LD was fragmented and heterogeneous.

In this sense, since the early 1950s, urbanization has been the main responsible for the conversion of rural land to urban practises, causing impacts on ecosystem function, structure and dynamics, such as loss of rural areas, soil degradation and landscape fragmentation (Delfanti et al., 2016; Garcia Latorre et al., 2001; Luck and Wu, 2002; Salvati and Zitti, 2007b; Salvati et al., 2007; Tanrivermis, 2003; Weng, 2007). Landscape fragmentation was a key factor determining increased land sensitivity to degradation (Salvati and Zitti, 2009a). Fragmented landscapes are characterized by weak connections between natural elements causing a deterioration of their ecological functions and negative impacts on biodiversity (Cook, 2002; Hidding and Teunissen, 2002; Jongman, 2002; Serrano et al., 2002; Wilcox and Murphy, 1985). As land fragmentation is commonly observed in agricultural systems on both regional, local, and farm level (Hidding and Teunissen, 2002), natural habitats and traditional crop systems require a sustainable management aimed at reducing patchiness and ecological isolation (Biasi et al., 2015). Land fragmentation and farm marginalization determine a progressive erosion of the agricultural base, causing less effective farm support operations and facilities, which raise operating costs (Lapping, 1979; Pfeffer and Lapping, 1995). With rapidly adjusting crop systems to the globally increasing demand of food, landscapes transformations in the Mediterranean basin reflect contrasting processes involving rural districts, spanning from crop intensification to farmland abandonment (Smiraglia et al., 2016). Especially crop intensification has frequently led to homogeneous rural landscapes with low natural, agronomic and cultural diversity, possibly associated to a high (and spatially homogeneous) level of land sensitivity to degradation (Mancino et al., 2016).

Preserving the spatial structure of high-quality farmland and crop mosaics is therefore a reasonable strategy with the aim to reduce negative environmental impacts of farming. In this sense, the ESAI allows identifying which areas require specific actions mitigating or reversing LD (Glenn et al., 1998; Hermann and Hutchinson, 2005). According to the results obtained, soil and vegetation are the most components related to spatially-heterogeneous conditions predisposing land to high sensitivity to degradation. Imbalanced environmental conditions in terms of natural capital require

measures minimizing soil degradation and protecting natural vegetation with the final objective to improve components' balance and spatial heterogeneity in LD (Hamdouch and Zuindeau, 2010). Together with soil and vegetation, climate quality is considered a component strongly associated with imbalanced ecological conditions possibly leading to LD (Feoli et al., 2003; Lavado Contador et al., 2009; Montanarella, 2007; Sivakumar, 2007). Local climate regimes are only indirectly influenced by environmental policies, suggesting implementing strategies for the mitigation of LD (Hermann and Hutchinson, 2005).

As stated by UNCCD, addressing land degradation and desertification in the Mediterranean region includes: (i) policy reforms and enforcement; and (ii) adequate research on sustainable land-use and restoration of previously degraded lands. To implement the UNCCD and the Italian National Action Programme (NAP), regional authorities must provide specific intervention plans, identifying the most sensitive areas to desertification and ensuring that future generations can benefit from a healthy soil (Artmann, 2016; UNCCD, 2012). Policies should incorporate measures reducing impacts of rapid biophysical and socioeconomic transformations particularly in marginal districts with low population density, limited accessibility and a usually rural organization (Esposito et al., 2016; Tan, 2006). Consequently, the present work outlines the pivotal role played by a comprehensive analysis of different components of natural capital as possible targets for combined environmental policies against desertification (Salvati and Zitti, 2008). In this ambit, diversification in the spatial distribution of an index of land sensitivity to degradation may represent an early-warning indicator of desertification risk.

While being spatially-heterogeneous, the increase in the level of sensitivity over the last 50 years requires mitigation actions specifically designed for sensitive districts with high H' and J index and a medium-high ESAI score. Land sensitivity to degradation is frequently interpreted as: a mixture of "risk exposure and stress, and difficulty coping with them" (Chambers, 1989), the potential loss (Cutter et al., 2003), the capacity to predict, to manage, to preserve against and to recover the pressure of a natural risk and the ability to be damaged (Rayner and Malone, 2001). Foreseeable scenarios should not be limited to the risks linked with climate change and biophysical conditions, but also be extended to the issue of socioeconomic sensitivity (Rayner and Malone, 2001).

Based on local-scale information, adaptive approaches offer a comprehensive framework for policy implementation and mitigation of negative externalities over different temporal contexts (Cushman and McKelvey, 2010; Vernier et al., 2009; Walters, 1986). For example, incentives and subsidies supporting specific farm types or farm-holder groups, individual crop or food products have often determined a spatially-diversified increase in land sensitivity with impact on desertification risk (Juntti and Wilson, 2004). The European Union soil thematic strategy, taken as a pertinent policy combating desertification, has identified threats to soil functions (e.g. erosion, salinization, compaction, sealing and contamination) and suggested regional-wide and place-specific practical actions to mitigate the negative impact of soil degradation (Montanarella, 2007). At the same time, EU subsidies for marginal rural areas sustained agricultural systems with low profits, producing a negative impact on soil quality while preserving biodiversity and traditional practices (Onate and Peco, 2005). In this sense, the results obtained contribute to the development of specific land policies for homogeneous and heterogeneous agricultural districts, informing effective mitigation strategies against desertification.

5.4. Soil matters in the Mediterranean Europe?

Soils support important ecosystem functions, demonstrating ability to recovery even in contexts where anthropogenic disturbance determines spatial variability in the use of land (Hubacek and van den Bergh, 2006; Verburg et al., 2008). However, if the acting pressures exceed certain limits, soils would be unable to perform pivotal tasks and become ecologically vulnerable (Lorent et al., 2008). Land capital assumes a fundamental role in local development (Robinson and Lebron, 2010; Roseta-Palma et al., 2010; Ferrara et al., 2016). Fertile soils have ensured the maintenance of a viable agriculture and rural settlements for centuries, indirectly promoting industrial growth in suitable areas (Hubacek and van der Bergh, 2006). In recent decades, urbanization processes, including urban sprawl and city shrinkage, have determined an increased consumption of soil resources (Verburg et al., 2008) and relevant impacts on natural environments, especially in peri-urban regions (Paul and Tonts, 2005; Aguilera et al., 2011; Inostroza et al., 2012; Salvati et al., 2015). Landscape transformations have been driven by historically-produced and place-specific processes, resulting in divergent socioeconomic outcomes (McCauley et al., 2015).

At the global scale, urban dispersion is a key socioeconomic issue (Couch et al., 2007) and a serious concern for sustainable development (Longhi and Musolesi, 2007). Being primarily driven by urban sprawl (Scalenghe and Ajmone Marsan, 2009), sealing of high-quality soils is considered a relevant threat for European environment (European Environment Agency, 2012). In the Mediterranean region, degradation and physical depletion of soil resources outline the intrinsic fragility of rural ecosystems and the impact of socioeconomic drivers leading to conversion of natural and agricultural areas to urban uses (Ferrara et al., 2014; Zitti et al., 2015). Although it was demonstrated that soil sealing may influence both structure and composition of socio-ecological systems (Salvati and Carlucci, 2013), the direct impact on economic structures and performances has been occasionally investigated (Verburg et al., 2013). A diachronic study reconstructing land consumption trends over the last 50 years in Italy (Salvati, 2013), reported that urbanization-driven land has involved soils with different economic value, depending on the observed pattern of urban expansion (e.g. compact vs dispersed). Compact urban expansion has been frequently demonstrated to consume low-quality soils resulting in degraded fringe landscapes (Salvati et al., 2012); conversely, an increased proportion of high-quality rural land converted into dispersed settlements was observed in Mediterranean Europe (Salvati et al., 2014a). Selective land take by urban expansion was frequently observed in Southern Europe (Garcia, 2010; Serra et al., 2014; Salvati and Ferrara, 2013). In northern Italy, Ceccarelli et al. (2014) identified land with high suitability to agriculture as the most threatened by dispersed urbanization. Ferrara et al. (2014) observed a mismatch in the spatial distribution of intensive cropland and high-quality soils, possibly determined by urban expansion.

Cited article

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Despite extensive research in land-use science, the relationship between local communities and soil quality has been occasionally investigated (Raymond et al., 2009; Dominati et al., 2010). Land-use changes and soil depletion may have unpredictable consequences on fragile landscapes, determining (or consolidating) disparities in the access to high-quality soils among competing actors (Ferrara et al., 2014). Consequently, urbanization-driven soil consumption has been sometimes

considered an issue of spatial justice when altering the distribution of high-quality soils along the urban gradient (Briassoulis, 2011). As a matter of fact, depletion of soil resources was demonstrated to be associated with territorial disparities, economic backwardness, rural poverty and increased human pressure on fragile rural districts (Salvati and Ferrara, 2014). Social inequalities and economic polarizations have influenced soil quality along urban-rural and elevation gradients in the Mediterranean region (Corbelle-Rico et al., 2012; Niedertscheider and Erb, 2014; Zitti et al., 2015). In addition to deregulated urban expansion (especially evident in Italian and Greek contexts), land mismanagement has produced a spatial divergence in the quality of natural resources, possibly influencing the local socio-ecological background (Salvati and Carlucci, 2014; Salvati et al., 2014b, 2015).

Original frameworks approaching socio-environmental phenomena along urban-rural gradients are fundamental to identify metropolitan districts affected by urban sprawl (Safriel and Adeel, 2008; Raymond et al., 2009). Local communities in the northern Mediterranean region are representative examples of the multifaceted relationship with heterogeneous environmental conditions determined by the interplay of demographic, cultural, economic and political factors (Salvati and Carlucci, 2011) and impacting (directly or indirectly) soil quality (Ferrara et al., 2014). Preserving high-quality soils should be recognized as a policy target, especially where agriculture is an essential component of district value added: however, this goal has been rarely considered in sustainable management of peri-urban land (Ferrara et al., 2014).

Our purpose is to investigate comparatively soil quality and urban expansion in 66 metropolitan areas from 5 southern European countries (Portugal, Spain, France, Italy and Greece). Land take and the characteristics of recently developed soils were evaluated distinguishing among compact, dispersed and mixed urbanization patterns with the use of high-resolution land-use maps. A comprehensive analysis of soil quality was based on a composite index integrating different soil attributes with the aim to assess the overall depletion in soil resources due to urbanization (Salvati et al., 2014a). The methodology proposed can be part of a geographic information system for regional planning and supporting decisions for a sustainable land-use management. Furthermore, this study provides an original analysis of the impact socioeconomic local contexts have on environmentally-fragile peri-urban regions in Mediterranean Europe.

5.4.1. A multivariate analysis of socioeconomic constraints to urban expansion

The northern Mediterranean region has a complex topography with distinct vegetation, soil and climatic zones that reflect place-specific factors shaping socioeconomic local contexts. The present study focuses on 66 metropolitan regions (Figure 5.8) > 100,000 inhabitants at the beginning of the 2000s belonging to one of the five Mediterranean European countries (Portugal, Spain, France, Italy and Greece). Portugal is represented by its capital city, Lisbon, and 5 majors urban centers (Setubal, Aveiro, Oporto, Faro, Coimbra). Eighteen Spanish metropolitan areas were considered including the capital city, Madrid, some northern cities (Santander, Bilbao), southern cities facing the Mediterranean Sea (Alicante, Malaga, Cordoba, Valencia, Murcia, Barcelona, Palma di Mallorca) and several internal cities (Badajoz, Zaragoza, Vitoria Gasteiz, Oviedo, Seville, Valladolid, Toledo, Pamplona Iruna). Nice and Montpellier are cities representative of the French Mediterranean region. The 31 Italian cities considered here are distributed homogeneously from the north to the south of the peninsula. Finally, Athens and other 8 cities (Volos, Kavala, Kalamata, Patras, Iraklion, Salonika,

Ioannina and Larisa) are representative of the Greek territory. The countries considered here are characterized by relevant socioeconomic disparities, such as Italy (northern vs southern regions) or Spain (more accessible urban regions vs less accessible rural districts). These differences reflect in soil quality, land-use structure and processes of landscape fragmentation in peri-urban districts (Salvati et al., 2011).

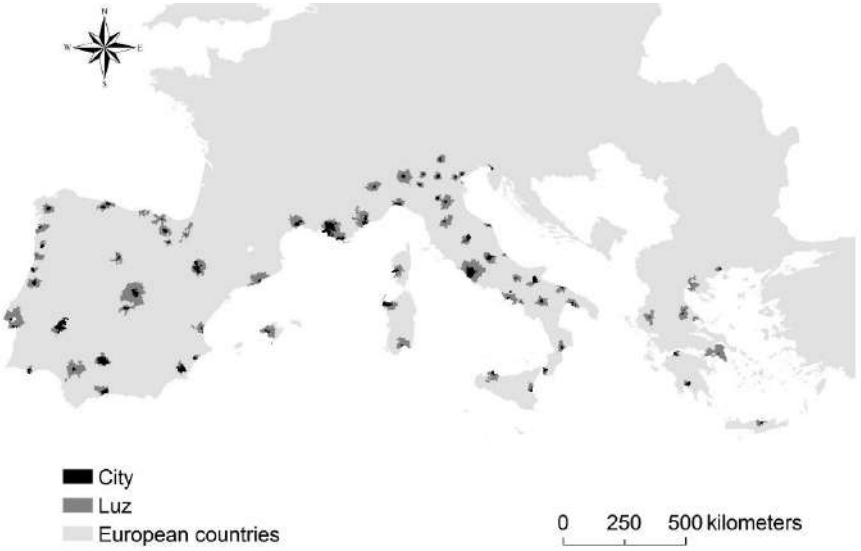


Figure 5.8. Distribution of inner cities and Large Urban Zones in Mediterranean Europe.

City boundaries were delineated according to the European Urban Areas statistical classification (http://www.urbanaudit.org/) of "Large Urban Zones", described by the Urban Audit program as regions from which a considerable share of the residents' commute into the central city (Eurostat, 2004). The objective of the Urban Audit program is to collect homogeneous data for cities with different socioeconomic and environmental characteristics, allowing for between- and within-countries comparisons (Guerois et al., 2012). Maps from the Urban Atlas (UA) program providing pan-European comparable land-use data referring to the late 2000s for inner cities ('City') and Large Urban Zones ('Luz') > 100,000 inhabitants as defined by the Urban Audit program were used. The UA nomenclature identified 20 land-use classes, grouped into 9 categories: dense urban fabric (sealed land > 50%; code 1); mixed urban fabric (30% > sealed land > 50%; code 2); discontinuous urban fabric (sealed land < 30%; code 3); service settlements (code 4); transport network (code 5); open areas with urban use (code 6); green urban spaces, wetlands and water bodies (code 7); cropland (code 8); and forests (code 9).

The Environmentally Sensitive Area (ESA) framework (Salvati et al., 2014b) was adopted with the aim to provide a comparative assessment of soil quality in the northern Mediterranean region using the Soil Quality Index (SQI). The SQI assesses soil resources and degradation processes composing 4 variables (soil depth, texture, parental material and slope) derived from the European Soil Database (European Environment Agency, 2009). The composite index was estimated as the geometric mean of the scores assigned to each of the four input variables ranging from 1 (the lowest vulnerability to soil degradation and, thus, the highest soil quality) to 2 (the highest vulnerability to soil degradation and, thus, the lowest soil quality). Variables' score system was derived from earlier studies (Salvati and Bajocco, 2011). The SQI map was disseminated as raster file covering Mediterranean Europe at 1 km^2 resolution excluding water bodies (Salvati and Bajocco, 2011).

Data on biophysical conditions and quality of soils (i) sealed during 2000-2010 or (ii) under stable non-urban use of land (cropland, forest) were derived from the overlay of the SQI raster map (dated late 1990s) and each UA land-use city map (dated late 2000s) using ArcGIS 9.3 (ESRI Inc, Redwoods, USA). Four thematic dimensions regarding with urban expansion and soil depletion spatial patterns were investigated in this study using 65 indicators evaluating (i) spatial patterns of soil consumption (n = 12), (ii) land-use (9), (iii) landscape structure (22), (iv) environmental and territorial context (7) and (v) socioeconomic background (15). Socioeconomic variables homogeneous over time and space were derived from Eurostat Urban Audit official statistics at a disaggregated resolution scale (Salvati and Carlucci, 2011).

Soil consumption patterns were addressed calculating the percent ratio of the average SQI score separately for 6 urban land-use classes to the average SQI score of agricultural soils (i-vi, 'a1' to a6') and forest soils (vii-xii, 'f1' to 'f6') in each metropolitan region. Land-use was investigated considering the percent area (i-ix) of classes 1 to 9 at each metropolitan region ("p1" to "p9"). Landscape structure was assessed calculating (i-xx) 20 class-level indicators of mean patch size (based on the UA land-use class nomenclature, (xxi) a landscape-level mean patch size ("MPS") and (xxii) a landscape-level Shannon H' diversity index ("Shannon H'"). The environmental and territorial context was described using (i) median SQI score of each metropolitan region linearly transformed in a score ranking from 0, the lowest soil quality, to 1, the highest soil quality ("MetSQI"), (i) percent coefficient of variation of SQI scores at the metropolitan scale ("cvSQI"), (iii) ratio of agricultural to forest SQI, based on transformed SQI scores ("Agr"), (iv) the rate of urban expansion during the investigated time period ("Urb"), (v) log-transformed metropolitan surface area ("Area"), (vi) an environmental index of desertification risk called the ESAI (Environmental Sensitive Area Index), taken as a proxy of land degradation and ranging from 2, the highest land degradation risk, to 1, the lowest land degradation risk (Salvati et al., 2014a) and, finally, (vii) per-capita built-up area (m^2, "pcUrb"). The socioeconomic context was finally described using (i-vi) 6 dummies identifying capital ("Cap") or coastal ("Sea") cities and the country each metropolitan region belongs (Greece, Italy, Portugal, Spain). Dummies' value depends on whether a given condition is satisfied ('1') or not ('0'); (vii) the ratio of 'City' to 'Luz' metropolitan surface area ("CLarea"); (viii) the ratio of 'City' to 'Luz' resident population ("CLpop"); (ix) the distance from the nearest 'Luz' ("Dist") calculated between the centroid of the two metropolitan regions; (x) population density (inhabitants/km^2, "Den"); population growth rate (%) at both (xi) 'City' ("popgC") and (xii) 'Luz' ("popgL") scale; (xiii) 'Luz' scale per-capita disposable income (euros, "Inc"), 'Luz' scale income growth rate (%) during (xiv) economic expansion, 2000-2007 ("ig0007") and (xv) recession, 2007-2013 ("ig0713"). Based on earlier studies (Ferrara et al., 2014; Salvati et al., 2015; Colantoni et al., 2016), background indicators selected in this work may provide a comprehensive overview of socioeconomic and environmental patterns and relationships at the base of soil consumption processes in Mediterranean cities.

A data mining strategy including descriptive statistics, spatial analysis and a Principal Component Analysis (PCA) combined the studied variables with the aim (i) to assess spatial linkages between urban expansion and soil quality and (ii) to identify multivariate relationships between soil quality and land-use possibly reflecting distinct patterns and processes of urbanization (Ferrara et al., 2014). A PCA was carried out to explore latent patterns in the data matrix composed of the selected indicators illustrated. Relevant components were retained based on the PCA

eigenvalues. Due to the high number of variables elaborated, components with absolute eigenvalues > 2 were extracted and analyzed. Component loadings and scores were used to profile spatial patterns of soil consumption observed in the study areas.

Table 5.8 reports a descriptive analysis of the selected indicators. On average, Spanish and Italian metropolitan regions are the biggest in southern Europe (respectively 1374 km^2 and 815 km^2), while French cities (386 km^2) are the smallest in the sample. Consumption of high- and low-quality soils was spatially-heterogeneous and depends on use and quality of non-urban land. High values of 'a' and 'f' indicators outline urbanization-driven selective consumption of soils with higher quality than the neighboring agricultural or forest soils. As a general pattern, rates of soil consumption under agricultural and forest use were relatively coherent over space. However, urbanization-driven land take involved more high-quality agricultural soils than forest soils. Residential urbanization consumed more high-quality soils than industrial/service settlements and infrastructures.

Table 5.8. Descriptive statistics (median value) of the indicators selected in this study by country (* absolute number).

Variable	France	Greece	Italy	Portugal	Spain
# metropolitan regions	2	9	31	6	18
Soil consumption patterns (index score)					
a1	1.11	2.13	0.53	-1.20	1.44
a2	2.47	-0.54	0.11	-0.37	1.53
a3	1.35	0.07	-0.05	-1.86	0.64
a4	0.35	1.74	0.49	-0.94	1.37
a5	1.31	1.66	0.37	-0.78	0.70
a6	1.52	-0.39	0.57	-1.11	1.82
f1	0.38	1.93	1.22	-0.26	3.06
f2	1.75	0.70	0.14	1.21	2.76
f3	0.62	-0.14	0.38	0.64	2.28
f4	-0.39	1.53	1.08	0.13	3.06
f5	0.58	0.73	1.03	1.47	1.40
f6	0.80	-0.95	1.03	0.03	3.47
Land-use (%)					
p1	9.9	2.1	2.4	7.1	1.5
p2	5.4	0.7	1.5	2.7	0.5
p3	3.0	0.8	3.7	2.6	1.9
p4	4.1	1.6	3.7	4.4	2.0
p5	5.7	2.2	3.5	5.0	2.3
p6	2.4	1.0	0.8	1.8	1.6
p7	39.1	75.8	63.8	51.2	75.6
p8	23.6	11.8	12.4	18.0	8.5
p9	9.9	2.1	2.4	7.1	1.5
Landscape structure (ha)					
MPS	4.3	11.3	4.3	6.0	9.8
P1110	0.6	0.4	0.6	0.6	0.5
P1121	1.7	0.9	1.7	1.0	0.8
P1122	2.3	1.1	2.3	1.1	1.1
P1123	1.8	1.0	1.8	1.0	1.2
P1124	0.6	0.7	0.6	0.7	1.0
P1130	0.5	0.5	0.5	0.5	0.5
P1210	1.6	1.6	1.6	1.8	1.7
P1221	8.3	22.2	8.3	6.7	17.2
P1222	71.8	34.9	71.8	40.7	34.0
P1223	4.5	5.1	4.5	5.2	4.9

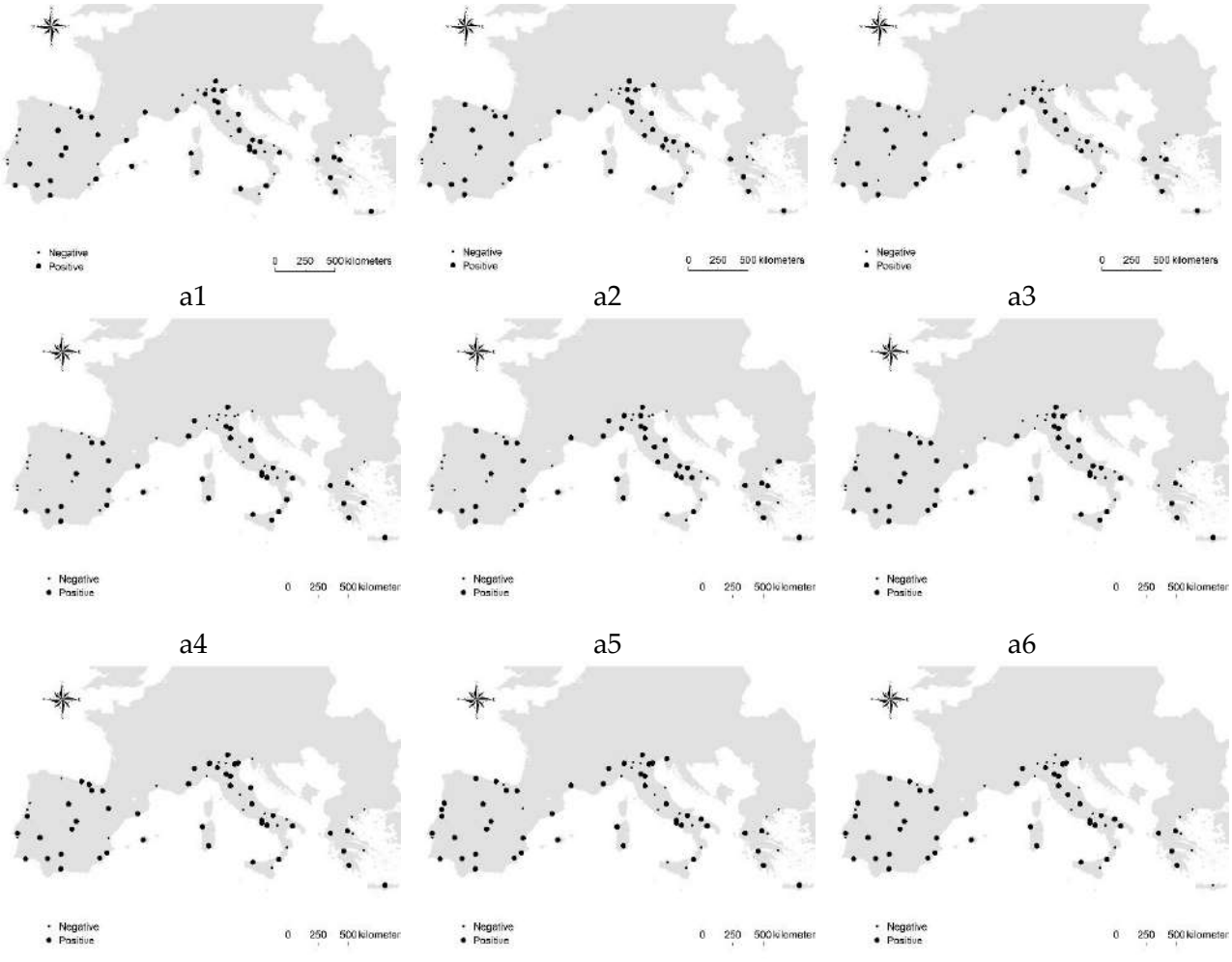
P1230	2.4	15.2	2.4	9.3	2.7
P1240	28.4	5.8	28.4	12.2	41.0
P1310	4.7	1.5	4.7	5.4	6.4
P1330	1.6	0.0	1.6	1.8	2.6
P1340	1.1	0.7	1.1	0.7	0.8
P1410	1.9	1.0	1.9	1.3	1.6
P1420	2.2	1.7	2.2	2.1	2.9
P2000	12.3	48.3	12.3	23.2	34.7
P3000	14.3	30.2	14.3	20.6	17.2
P5000	20.8	5.8	20.8	5.1	10.0
Shannon H'	0.4	0.7	0.5	0.7	0.4
Environmental constraints					
Urb (%)	3.29	0.86	1.59	2.51	1.13
MetSQI (score)	0.58	0.44	0.50	0.48	0.53
cvSQI (%)	1.19	2.49	1.56	1.19	1.84
ESAI (score)	1.25	1.46	1.36	1.34	1.35
Agr (score)	-0.73	-0.30	0.77	2.39	1.26
pcUrb (m^2)	187	318	365	376	265
Area (km^2)	386	587	815	414	1374
Socioeconomic background					
CLarea (relative proportion)	0.17	0.09	0.22	0.31	0.17
Cap (absolute number)	0	1	1	1	1
Sea (absolute number)	2	8	7	15	5
Dist (log-km)	2.11	2.11	1.87	1.74	2.00
Den (inhabitants/km^2)	283	332	576	487	378
CLpop (relative proportion)	0.64	0.72	0.54	0.52	0.63
pgC (relative proportion)	0.60	-0.54	0.04	0.21	0.17
pgL (relative proportion)	0.80	-0.31	0.04	-0.26	0.04
Inc (per-capita Euros)	13,719	20,199	30,565	24,755	15,727
Ig0007 (%)	5.39	9.11	4.07	5.74	9.78
Ig0713 (%)	2.23	-3.87	-0.04	-0.71	-0.93

Urban expansion ('Urb') reaches the highest percent annual rates in French (3.3%) and Portuguese cities (2.5%). However, urban growth consumed low-quality agricultural soils in Portuguese cities (all indicators 'a' assumed negative values); compact residential urbanization also consumed low-quality forest soils (f1 = -0.26). The percent annual rate of urban growth was the lowest in Greece (0.86%) but compact residential urban expansion, industrial settlements and infrastructures consumed soils with particularly high quality compared with the surrounding non-urban soils (with both agricultural and forest use). High-quality soil consumption was observed for all land-use classes; however, urban expansion consumed high-quality forest soils in a higher proportion than agricultural soils. Mixed (compact and dispersed) residential urbanization consumed soils of particularly high quality in French and Spanish cities.

Landscape structure indicators (p1 to p9) indicate French and Portuguese metropolitan regions as the most compact in the sample investigated. Discontinuous settlements were more diffused in French and Italian cities. Results also indicate that the highest landscape diversity (Shannon H') was observed in French and Portuguese cities (respectively 0.73 and 0.68). Overall soil quality index was the highest in French and Spanish cities, with the largest spatial variations observed in Greek and Spanish cities. Non-urban land was primarily used for agriculture in Spanish and Greek cities and for forestry in Portuguese and French cities.

The economic performance of Mediterranean cities before (2000-2007) and during (2007-2013) recession diverged considerably. Greece, Portugal, Spain and, partly, Italy, featured negative rates of income growth during 2007-2013, opposed to remarkably positive rates during the pre-crisis time interval. Positive growth rates in both time periods were observed only in French cities. French cities concentrated also the highest level of per-capita declared income, preceding Italy and Spain. Population growth rates were moderately positive at the 'City' scale, declining slightly at the 'Luz' scale, with the exception of Greek cities where the reverse pattern applies.

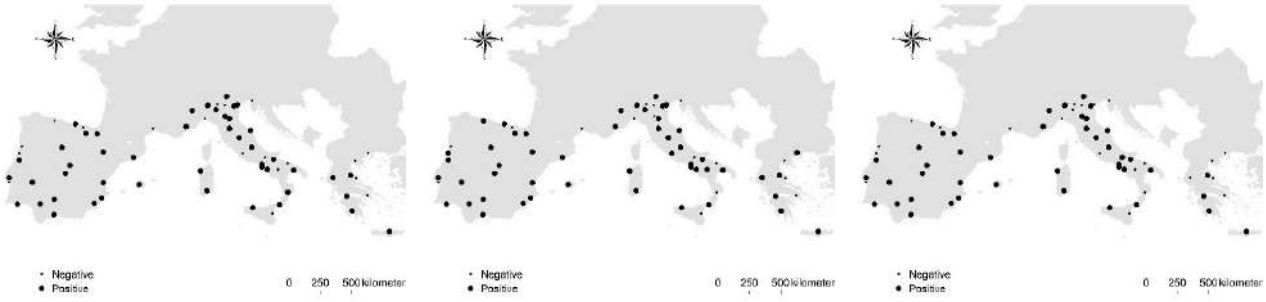
Maps illustrated the spatial distribution of relevant soil consumption indicators in 66 metropolitan regions of southern Europe (Figure 5.9). The purpose is to define the predominant pattern of soil consumption, i.e. the ratio of the SQI of agricultural land (expressed as 'a1' to 'a6') to the SQI of forest land ('f1' to 'f6') covered by each urban land-use class. For each metropolitan region, the indicator's value was illustrated with small dots when negative (consumption of below-average quality soils) or large dots if positive (consumption of above-average quality soils). Spanish and Greek cities (in particular coastal cities as Patras, Alicante and Palma de Mallorca) consumed high-quality agricultural and forest soils (positive 'a1', 'a2' and 'a3' indicators); negative values are mainly associated with Portuguese cities.



a1 a2 a3

a4 a5 a6

f1 f2 f3



f4 f5 f6

Figure 5.9. Spatial distribution of selected indicators of soil consumption in 66 European Mediterranean cities.

The PCA extracted 4 relevant components accounting for 47.7% of the total variance (Table 5.9). Component 1 (20.3%) identified the urban¬-rural gradient in the studied cities (respectively oriented from negative to positive scores), with medium-small urban areas characterized by un-fragmented and poorly diversified landscapes. A generalized consumption of high-quality soils was observed in metropolitan regions with high proportion of crops areas, large patches, high quality of agricultural soils (in respect to forest soils) and high spatial variability of soil quality at the metropolitan scale. In these regions, population density, percentage of urban settlements in total area, per-capita income and income growth rate during recession were lower than the sample's average. However, these cities totalized a below-average rate of land take. This result indicates a progressive decoupling of land take from consumption of high-quality soils.

Table 5.9. Results of a Principal Component Analysis applied to the indicators' matrix (loadings > |0.4| were reported) *.

Dimension	Variable	PC1	PC2	PC3	PC4
Soil consumption	a1	0.65			
	a2	0.55			
	a4	0.64			
	a5	0.60			
	a6	0.59		0.40	
	f1	0.71	0.52		
	f2	0.65	0.51		
	f3	0.56	0.54		
	f4	0.71	0.43	0.40	
	f5	0.66	0.50		
	f6	0.65	0.48		
Land-use	p1	-0.70			
	p2	-0.70			
	p3	-0.53			
	p4	-0.71			
	p5	-0.65			
	p6		0.54		
	p8	0.63			
	p9		-0.41		
Landscape structure	MPS	0.67		-0.48	
	Shannon H'	-0.83			
	P1110	-0.51	0.45		
	P1121	-0.51	0.48		
	P1122		0.54		
	P1123		0.46		
	P1124		0.41	-0.48	

	P1130		0.53		
	P1210		0.52		
	P1221				0.47
	P1330			-0.48	
	P1340		0.47		
	P1410		0.63	-0.42	
	P1420		0.50		
	P2000	0.42		-0.52	
Environ. constraints	Agr	0.43	0.43		-0.41
	Urb	-0.82	0.43		
	MetSQI		0.48		
	cvSQI	0.63			
	Area			-0.50	
	pcUrb		-0.45		-0.44
Socioecon. background	Greece				0.71
	Italy				-0.46
	Spain			-0.49	
	Sea				0.64
	Den	-0.55			
	CLpop	0.51			
	PgC		0.44		-0.41
	Inc	-0.45			-0.42
	Ig0007	0.48		-0.41	
	Ig0713	-0.43			-0.63
	Expl.Var.%	*20.3*	*12.4*	*8.2*	*6.8*

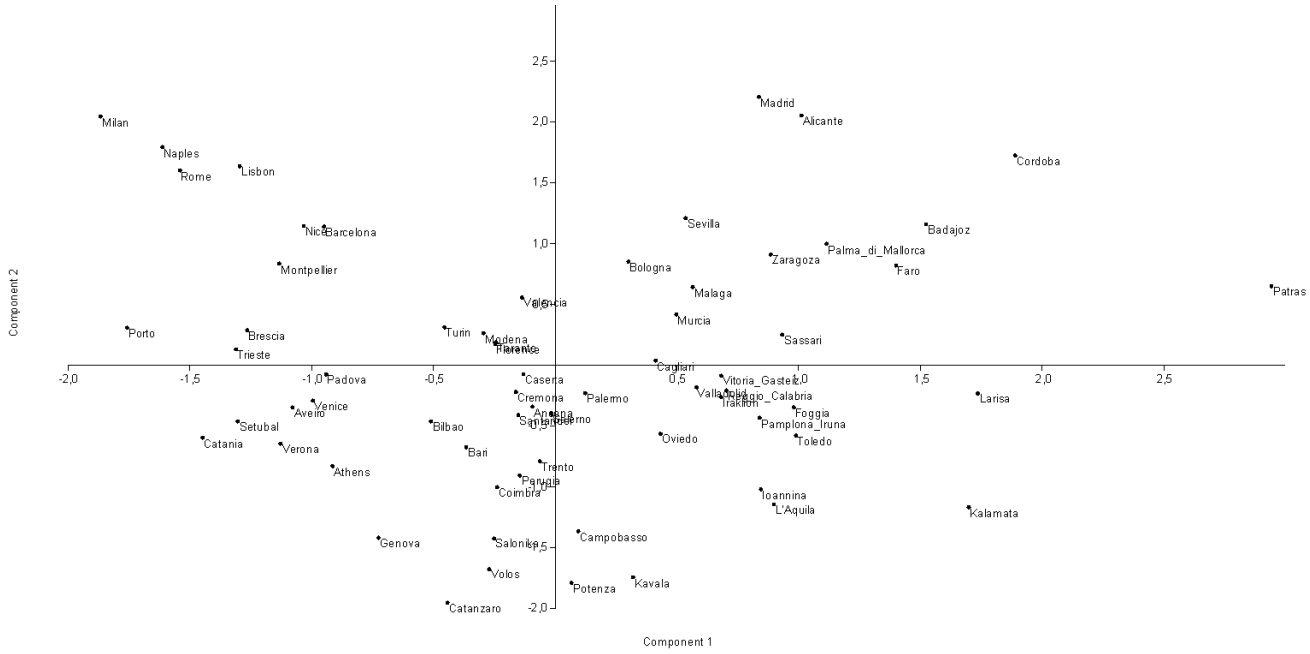
* a3, P1222, P1223, P1230, P1240, P1310, P3000, P5000, Portugal, pgL, Dist, CLarea and Cap were associated with non-significant loadings.

Component 2 (12.4%) was associated with consumption of high-quality forest soils (positive loadings), in turn positively correlated with (i) proportion of open areas with urban uses (including construction areas and abandoned fringe land), (ii) size of urban patches, (iii) rate of land take, (iv) overall soil quality and (v) population growth in central cities. Metropolitan regions where consumption of high-quality forest soils was observed are characterized by (i) low proportion of forest land in total area, (ii) low value of per-capita built-up area and (iii) low quality of forest soils in respect to agricultural soils. These results indicate that traditionally compact and land-saving cities were expanding more rapidly in the last decades consuming preferentially high-quality forest soils than high-quality agricultural soils.

Component 3 (8.2%) outlined place-specific factors affecting high-quality soil consumption. In small metropolitan regions, high landscape fragmentation, moderate income growth during 2000-2007, high quality agricultural and forest soils were respectively consumed by open areas with urban uses and service settlements. Finally, component 4 (6.8%) identified industrial cities with a predominance of high-quality forest soils, concentrating in Greece or along the sea coast, with low values of per-capita built-up area, per-capita declared income, income decline during 2007-2013 and population decline in central cities.

Each metropolitan region was profiled based on distinctive soil consumption patterns using component scores. Figure 5.10 documents how Mediterranean cities were grouped into specific clusters according with scores to components 1 and 2 and to components 3 and 4. Cities that have consumed a large quantity of high-quality agricultural and forest soils are concentrated on the right side of plot (a). This group included heterogeneous, medium- and low-size cities in Spain, Italy and Greece (e.g. Patras, Cordoba, Larisa, Kalamata). Madrid was the only large city participating in this

group. Large cities were preferentially clustered on the left side of plot (a). The upper left quadrant identified dense and compact metropolitan areas (Milan, Rome, Barcelona, Lisbon, Naples) characterized by high rate of land take and consumption of low-quality agricultural soils and high-quality forest soils. Metropolitan regions expanding on low-quality agricultural and forest soils were clustered in the lower left quadrant including compact, large cities in Greece (Athens, Salonika) and southern Italy (Bari, Catania). The left side of plot (b) included several Spanish cities (including Zaragoza, Seville, Cordoba, Murcia, Valladolid) and large cities in both Italy and Greece, being characterized by a below-average consumption of high-quality soils by service settlements and construction sites. Small- and medium-size cities in Spain, Italy and Greece, characterized by spatially-diversified consumption of high-quality soils, were clustered along the right side of plot (b).



(a)

(b)

Figure 5.10. Score plot illustrating the position of studied metropolitan regions within the selected principal components (plot a: component 1 *vs* 2; plot b: component 3 *vs* 4).

5.4.2. Soil quality around Mediterranean Europe

Landscape and soil depletion are major concerns in the European political agenda (European Environment Agency, 2006; Salvati, 2014; Serra et al., 2014). Soil quality is recognized as a powerful driver of local development (Delbecq et al., 2014), being negatively influenced by population growth and increased human pressure in both affluent and emerging countries (Meeus, 1993). In recent decades, suburban areas became desirable places for dispersed settlements due to lower land and commuting prices than urban areas (Hubacek and van der Bergh, 2006). In southern Europe, a relevant proportion of non-urban land surrounding central cities has recently undergone dispersed urban expansion (European Environment Agency, 2006), leading to a substantial loss of fertile soils (Aguilera et al., 2011) with negative impacts on natural environments (Marull et al., 2009). While low-quality soils have supported, for a long time, forests and pastures, with cropland being concentrated on fertile soils, built-up areas are more recently competing with agricultural areas for high-quality soils (Salvati et al., 2014a). This process negatively influences economic viability of the primary sector and sustainable provision of basic ecosystem services in peri-urban regions (Paul and Tonts, 2005).

Consequences of spatial processes linking urban sprawl to consumption of fertile soils are difficult to predict and manage (Zhao et al., 2013). To increase knowledge of such complex issues, the approach proposed in this study was based on the integrated use of multi-criteria environmental indicators and data mining techniques (Ferrara et al., 2014). The study investigates the overall quality of soils lost under different forms of urban expansion (compact, dispersed, mixed) in 66 metropolitan regions of southern Europe. The indicators elaborated here have attempted to define specific territorial and socioeconomic profiles in a representative sample of Mediterranean cities. The work provides a comprehensive information base that may support integrated policy decisions

orienting sustainable urban growth processes, e.g. by reducing high-quality soil consumption (Macleod et al., 2007).

Empirical findings indicate a generalized loss of high-quality soils in peri-urban areas. However, this pattern is spatially heterogeneous since high-quality soils were consumed primarily in small-size metropolitan regions with medium-low population density and a moderate level of per-capita income (Salvati et al., 2014a). Although expanding rapidly, large cities with highly diversified landscapes are consuming low-quality agricultural and forest soils. High-quality agricultural soils, less fragmented landscapes, growing incomes and a considerable proportion of construction sites and land without current use (indicating land under conversion to urban uses) are typically associated to socioeconomic contexts with large consumption of high-quality soils.

Our results are in partial agreement with earlier studies focusing on landscape transformations driven by urban expansion (Verburg et al., 2008). Socioeconomic implications of land-use change include loss of high-value land (Serra et al., 2014; Salvati and Ferrara, 2013), degradation of pervious soils around settlements (Salvati et al., 2014a) and landscape fragmentation (Ferrara et al., 2014). Land availability and soil quality were pivotal factors affecting distribution of recently developed settlements (Irwin et al., 2003; Magliocca et al., 2015; Colantoni et al., 2016). The study has demonstrated over space that metropolitan regions with low-quality non-urban land exposed to desertification risk expanded systematically on soils with below-average quality in respect with neighbouring soils (Barbero Sierra et al., 2013). Similar patterns of soil consumption were observed for compact and dispersed settlements. However, mixed settlements are associated to a higher rate of high-quality soil consumption than compact and dispersed settlements.

Agglomeration and location variables also play a key role on urban development decisions, determining an increased rate of land consumption (Wu and Cho, 2007). The study evidences how city size, landscape composition, disposable income and population density shaped diversified spatial patterns of soil consumption at the metropolitan scale. Especially population density and income levels had a relevant impact on high-quality soil consumption. In all Mediterranean countries, dense and affluent cities consumed soils of lower quality in respect to the rest of the sample. These outcomes corroborate earlier results presented by Salvati et al. (2012) and suggest the key role of unregulated urban expansion and real estate speculation in rising rate of high-quality soil depletion, especially in peripheral socioeconomic contexts (Giannakourou, 2005). With this perspective in mind, the rate of low-quality soil consumption is higher in large metropolitan regions than in smaller regions. Taken together, land-saving dense settlements proved to be more sustainable in rapidly-growing Mediterranean cities, consuming low-quality soils more frequently than mixed and discontinuous settlements (Montanarella, 2007). Place-specific factors seem to be relevant in determining spatial polarization in urban areas consuming soils with high and low quality (McCauley et al., 2015). Soil quality increases with landscape diversity and decreases with the share of cropland in total landscape (Recanatesi et al., 2016).

The environmental and socioeconomic indicators used in this study are promising tools to investigate land consumption, a multi-domain problem that influences several dimensions of urban sustainability (Zuindeau, 2007). Identifying factors that determine land take is indispensable to contain urban expansion (Verspagen, 2010) and to reduce depletion of high-quality soils (Salvati et al., 2015; Ferrara et al., 2016). The joint analysis of soil consumption and urban transformations

contributes to identify alternative policies of regional development and to design targeted measures improving efficiency in the use of land (Verburg et al., 2008). Earlier studies have tried to support policy makers evaluating optimal use of non-urban land (Verburg et al., 2013), proposing measures able to minimize the negative impact of urban expansion on landscape functions (van Ittersum et al., 2004). In this study, a new perspective was proposed in the analysis of the environmental consequences of urbanization processes, separating the general notion of 'land take' from more specific measures of 'high-quality soil consumption'. It was demonstrated that these dimensions are spatially decoupled in the studied sample of cities, being associated to different socioeconomic factors. Findings shed new light in the debate on urban sustainability, indicating that land-saving cities should be identified according to a (desirably low) rate of land take with preference for low-quality soils. Measures promoting a sustainable urban development should include the two criteria mentioned above, considered as relevant dimensions in both environmental assessment and evaluation of policy effectiveness (Ferrara et al., 2014).

Assessing the efficiency of land-use policies is a key tool to improve urban conditions for environmental sustainability and socioeconomic resilience (Rotmans et al., 2000; Wester-Herber, 2004; Serra et al., 2013). Complex socioeconomic contexts where multiple agents shape urban expansion may influence planning decisions oriented towards a sustainable use of land (Salvati and Carlucci, 2014). Improved tools quantifying soil consumption over time are necessary to quantify effectiveness of land management and environmental conservation measures (Colantoni et al., 2016). Results indicate that land protection regimes should be enhanced in high-quality open areas, close to forests and mixed cropland, intended as suitable sites for discontinuous urban expansion (Salvati et al., 2015). Integrated strategies for sustainable development are increasingly required to consider social cohesion, economic growth and environmental quality as joint policy targets in areas with low-quality soils (Ferrara et al., 2014; Teixeira et al., 2014). Regional plans merging environmental and socioeconomic measures may limit consumption of high-quality soils, in turn reducing the negative impact of sprawl.

5.5. Forest fires

Every year forest fires that occur nationwide in Italy cause incalculable damage, not only from the standpoint of forestry, but also from the economic point of view, social and human lives. It has been shown that 98% of them are directly attributable to man, for imprudence, non-compliance of the regulations, or to the searching for illegal profits. The result is that forest fires, despite the predisposing factors such as abundant dry vegetation, poor rainfall, and high temperatures, are not a natural phenomenon, because without a trigger generated by man, the plant biomass, to get to the spontaneous combustion, should reach temperatures around 300 °C. Almost all forest fires are therefore attributable to arsonists or pyromaniac (in the second case the subjects are affected by a pathological obsession), with many different causes; it is therefore very difficult, in any investigation, to find out what was the reason. Also, to be noticed, is that the development of forest fires, not only a social impact (Irland, 2013; Collins et al., 2013), with high costs for extinguishment operations, but also on biodiversity, and effects on vegetation (Tessler et al., 2014; González-Gómez et al., 2013), and the microbial population (Holden et al., 2015), not excluding the fact that, these events disperse elements and chemical compounds in the environment that can persist over time (Poupkou et al., 2014; Choi, 2014; Slezakova et al., 2013; Silva et al., 2014). It is therefore important to develop systems to monitor (Kalabokidis et al., 2013; Wang et al., 2014) and to prevent fires by analyzing also the chances and the dissemination of the events aiming for interventions in forested areas as with political and social plans (Boubeta et al., 2015; Nuryanto 2015; Tian et al., 2013; Sanjuan et al., 2014; Bao et al., 2015; Ekayani et al., 2016; San-Miguel-Ayanz et al., 2013).

Cited article

Cossio, F., Riccioni, R., Zambon, I., Mazzocchi, F., Mosiello, M., Monarca, D. (2016). Forest Fires In Viterbo Province And In Lazio Region, In 1997-2012 Period: Origin, Frequency And Incidence. Contemporary Engineering Sciences 9 (27), 1305-1314.

5.5.1. Fires in Viterbo province and Lazio region

The purpose is to analyze the place of the elaborate early forest fire that occurred on the territory of the Lazio region and in particular the province of Viterbo, specifying for each province, from which place and in what number is the distinguishing fires originate in 8 territorial categories: forest, agricultural fields, fallow, pasture, railway, road, landfill and more by referring to the period 2003 to 2012. It has been also observed annual area (Ha/year) covered by events, always referring to all provincial land areas and weighted with the regional average for the years of 2000-2012 reference.

The study was then compared with the trend of regional rainfall during the same period (1997-2012) analyzing both the amount of annual precipitation (mm) and the number of rainfall events that occurred during the reference years, whose values were taken from the regional database, and then putting in correlation values of the fires and the incidence of recorded rainfall, since it has a link between rainfall trend, thermometer and gunpowder events.

Starting from the annual values, it has been defined the total number of fires for each province; considering the annual average number of fires from 1997 to 2012, it is shown that the province of Viterbo (43.625 events) remains well below the regional average (87725 events), taking into account that the total number of fires in the territory of Tuscia was 698, while that of the Lazio Region, for the same period, was 7018 (value that also includes those of the Province of Viterbo); from these

data, which express the trend in the number of fires, it can be observed that the Province of Latina (2790 cases) recorded the highest number of forest crimes from 1997 to 2012, followed by the Province of Frosinone (1699).

It is clear that the regional data are much more erratic over the years, registering a difference between the minimum and maximum of 123 fires (the maximum value was recorded in 2007, with 150.4 fire, and the minimum value in 2002, fires with 27.4), while the capital of Tuscia registered a difference between minimum and maximum of 82 events (the maximum is in the year 2012, with 98 fires and the minimum in the year 1999, with 16 fires (Figure 5.11-12).

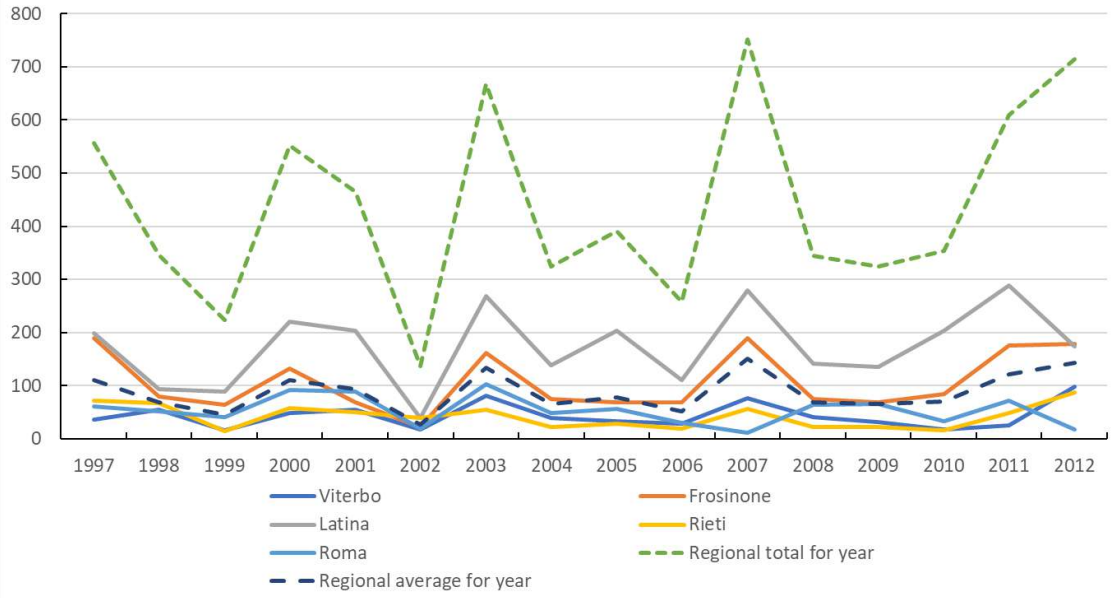


Figure 5.11. Number of fires per province, per year (years 1997/2012)

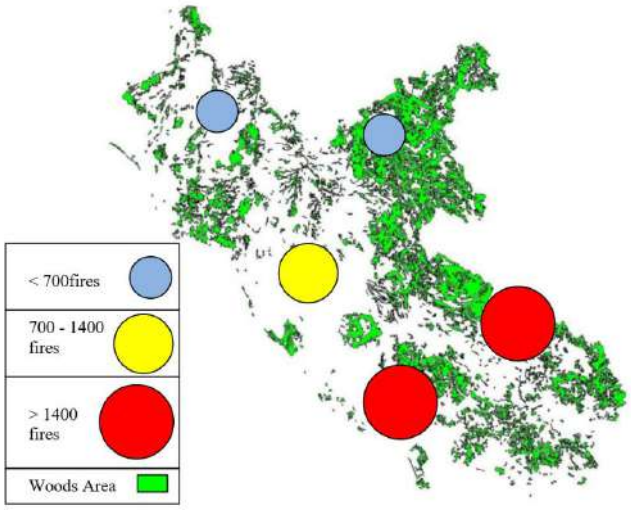


Figure 5.12. Distribution woods in Lazio region and number of fires for each province per year (years 1997/2012).

The data of forest fires for the Lazio region, registered since 1997 to 2012, indicate where and in what number fires have originated from, grouping all locations where fires have originated from in three main categories: forest, agricultural land and roads.

Analyzing the data relative to Viterbo province (Table 5.10), it was found that most of the forest fires had no direct origin in the forest, that as starting location corresponds to only 38% of the total, but rather in the other two types with 62% of the events.

Table 5.10. Number of forest fire in Viterbo province, divided by starting location.

Year	Forest	Agricultural land	Roads	Total
2003	34	18	29	81
2004	16	12	11	39
2005	17	6	10	33
2006	10	8	10	28
2007	25	17	34	76
2008	15	11	15	41
2009	9	5	18	32
2010	2	11	5	18
2011	11	8	6	25
2012	36	29	33	98
Total	175 (38%)	125 (26%)	171 (36%)	471 (100%)

With regard to the area affected by fires in each province, for the years 2000 to 2012, the territory of Tuscia turns out to be the least susceptible to fires, with an annual average area covered by fire of 176.28 hectares (for a total of 2291.67 Ha), against 887.53 hectares of Frosinone (11537.96 Ha), 1930.12 hectares of Latina (25091.61 Ha), 204.07 hectares of Rieti (2652.986 Ha) and 362.80 hectares of Rome (4716.43 Ha). The values obtained for all the provinces were then compared with the regional average (712.18 ha / year).

Regarding the data on the incidence of rains recorded, particularly focusing on the of Viterbo Province in which in the year 2012 were observed a maximum of 98 fires, to which, however, does not correspond a minimum value of precipitation (recorded, instead, in 2007), compared with the incidence of forest fires (Graph 1), it is evident that, at the moment when the broken line relative to the performance of the rains recorded a negative slope, the one relating to the number of fires, instead, records a positive slope; this means that to the decreasing amount of water rained during the year corresponds an increase in the number of fires which occurred during the same period.

It can be noticed also that in 2010, the year in which the highest level of precipitation was recorded (92.9 mm), the number of fires was 18 and in 2007, year which records the level of minimum rainfall, the number fire events rose to 76.

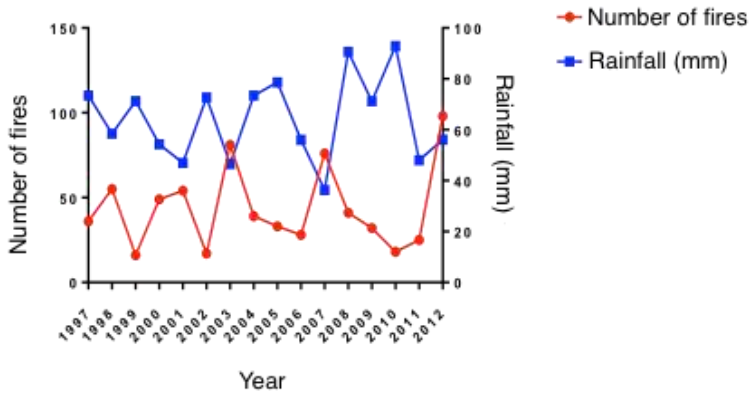


Figure 5.13. Comparison number of fires/precipitations

5.5.2. Temporal incidence of forest fires

The analysis of the incidence of forest fires showed that the most common starting locations are: the forest itself, with an incidence rate of 38%, the agricultural lands with 26% and roads by 36%, and it may be concluded that most forest fires had not begun directly in the woods, attesting its percentage to around 1/3 of the total forest fires, value that slightly differs from those of the other two types (agricultural lands and roads).

Regarding their extension, for the years 2008 to 2012, the most frequent forest fires in the Viterbo Province are those that do not exceed one hectare, with a total of 84 events (35.96 hectares of the total area covered), while those that create more damage to forest areas are those that have an extension between 5 and 50 ha, which destroyed a total forested area equal to 1009.55 Ha (55 total events); the most common forest fires in the Lazio region instead are those with an area between 1 and 5 hectares, with a total of 839 events (2112.28 hectares of the total area covered), while those who have created more damage to forests, even in this case, are those of extension between 5 and 50 hectares, which have destroyed, in the reference years, a total area of 11687.73 hectares, for a total of 756 events.

Crossing the data on fires and precipitations (which are of stronger influence than the temperature on the incidence of forest fires), the decrease of the average annual millimeters of rain fell on the ground corresponded to an increase in the number of fires for the same year, confirming therefore, a close correlation between the two phenomena. This correlation is also demonstrated by some institutional studies, which have shown that, depending on the intensity, the rains have different influences on fires. In particular, rainfall of significant intensity influences the water content of the wooden fuel still alive, while even low-intensity rainfalls have relevance on the dead tissues; more important, however, is the temporal distribution of rainfall: rainfall of low intensity, but well distributed over time, lower the fire danger, while keeping a high moisture content in both living and dead wooden fuels.

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6. Smart contexts towards sustainability

Smart cities mean a conceptual urban development model in which the integrated use of human, technological and collective capitals enable to improve urban agglomerations. According Angelidou (2014), the abuse and the distortion of the concept 'smart', which labels everything that appears original and innovative, are amplified by the conflicting interests between various stakeholders (such as local governments, citizens and research institutes). For this reason, it is difficult to recognize a universal definition of "smart city" among all those that have been given until today (Allwinkle and Cruickshank, 2011; Chourabi et al., 2012; Lombardi, Giordano, Farouh, and Yousef, 2012; Nam and Pardo, 2011; Papa, Garguilo, and Galderisi, 2013; Wolfram, 2012). Strategic planning for the development of smart cities is still limited due to the existence of a strong interdisciplinary (Angelidou, 2014). While the 'smart' term is used interchangeably in the literature (Hollands, 2008; Pardo, Nam, and Burke, 2012; Wolfram, 2012), the strategic planning for the development of smart cities remains unknown and shortly discussed (ABB, 2012; Chourabi et al., 2012; Nam and Pardo, 2011).

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Zambon, I., Monarca, D., Cecchini, M., Bedini, R., Longo, L., Romagnoli, M., Marucci, A. (2016). Alternative Energy And The Development Of Local Rural Contexts: An Approach To Improve The Degree Of Smart Cities In The Central-Southern Italy. Contemporary Engineering Sciences 9 (28), 1371-1386.

Cities consume 75% of worldwide energy production, generating the 80% of CO2 emissions (Lazaroiu and Roscia, 2012). Smart Cities Initiative aims to go towards local sustainable energy systems (Meeus et al., 2011). For example, urban mobility causes several problems (e.g. traffic congestion, energy consumption), that can be resolved with original solutions (e.g. adoption of vehicle-to-vehicle and vehicle-to-infrastructure communication networks and Intelligent Transportation Systems). Smart energy grids represent the main requirement in order to leverage energy consumption between the numerous stakeholders. Energy efficiency and savings can be achieved by the combination of intelligent and technologies in both residential and commercial markets processes (Correia and Wünstel, 2011). According to Neirotti et al. (2014), the required optimization during the use and the exploitation of tangible and intangible goods can be reached following various approaches, that are mainly related to: the way in which cities can orient themselves to achieve this objective; and the domains that are critical for a more intelligent use of urban resources. Cities seek to offer innovative services (e.g. for the smart energy management, intelligent lighting/electricity control and monitoring) (Palmieri et al., 2016). However, energy grids, natural resources, energy and water management, waste management, environment, transport, mobility and logistics are considered as the hard domains (Neirotti et al., 2014). Policies are sensible to the interacting factors that should be mapped to have a clear vision of strategic decisions (Angelidou, 2014). Traditional urban landscape is influenced by local characteristics, priorities and needs; but in smart cities, technology and global market forces affected it (Angelidou, 2014). The implementation of smart technologies offers the greatest challenge of the city governments (Akçura and Avci, 2014). Compared to traditional cities, smart cities enjoy new favorable network infrastructure allowing socio-economic, environmental and cultural improvement with a proactive government approach, generating various values added as such as well-organized meeting and sustainable partnerships (Santinha and de Castro, 2010; Allwinkle and Cruickshank, 2011; Deakin and Allwinkle, 2007). The European Union has already set goals, elaborating a wide range of

technologies and methods available (European Union, 2012). For energetic issues, methods focus on the improvement in terms of efficiency, cleanness and safeness, using sustainable renewable sources and reducing pollutant emissions (Lazaroiu and Roscia, 2012).

6.1. Italy and an attempt to understand which contexts to develop

Italy has progressed by increasing the renewable energy plants. In 2011, about 30% of the national electricity production was obtained from renewable energy sources (AEEG, 2012). In biennium 2010-2011, a remarkable increment of 466% from photovoltaic technologies and the 14% and 8% increases from biomass and wind, respectively, show a progressive incentive for renewable energy sources (Crispim et al., 2014). This data also emerged from the implementation of the actions from the Covenant of Mayors, that different contexts, such as smart cities candidates, have elaborated to achieve the EU target 20-20-20. For the development of "smart cities", action plans for sustainable energy (or Covenant of Mayors) offer themselves also as instruments for the development of a sustainable strategy.

The best performing cities, in the themes of smart sustainability, are concentrated in the northern Italy (report EY; 2016; report Between, 2014, 2013), highlighting the perpetual bipolarity that has always characterized the peninsula. Northern cities have a solid social and economic structure that allow a greater system efficiency. Such energy-consuming contexts are opposite to the more Central - Southern areas, where the rural connation reigns in their territory. However, in the latter where the primary sector is the lion's share, renewable energy plants, such as solar and wind, are intensely concentrated.

Based on the score obtained in the recent reports for smart cities, the aim was to analyze Italian contexts to reflect renewable energy and to offer concrete strategies that can make more sustainable those less virtuous situations. Starting from their local intrinsic characteristics, potential opportunities and useful actions are suggested to increase their smart degree, without focusing only to urban areas but also enhancing their agricultural vocation. The setting up of agro-energy districts can be a reliable solution for increasing employment, enabling greater energy self-sufficiency, additional protection of traditional rural landscapes and the rise of a circular economy which aims to re-use agricultural waste. Cities can make more innovative, self-reliant and sustainable their economies and territories, in addition to earning places in the ranking of smart cities through targeted policies and actions.

Italian authorities identify 20 regions, which are divided in a total of 116 provinces. Provinces are considered as the main territorial unit. The unit of analysis has gone down to the level of the 116 cities considered by the report of smart cities, to analyze and compare their intrinsic characteristics and to perform statistical analysis and GIS processing.

The study has examined three recent reports of smart cities in Italy (for the years 2013 and 2014 elaborated by Between and for the year 2016 by the research team of EY), which identify the most virtuous contexts in terms of smart cities. The score obtained by each city is considered as a key indicator for the investigation. Furthermore, other 81 indicators were processed, which have been collected from the database available into the web site of the National Statistical Office (Istat). Most of them refer to the last census (regarding the population, agriculture, industry etc.), carried out in 2011. The indicators developed usually define the standardization of the selected variables compared to its provincial area surface, identifying where the most interesting contexts are located.

In this way, Italy is described at the province level, following various themes (agriculture, economy, society and mobility). The survey was continued analyzing and zooming the energetic, mobility and environmental characteristics of the 116 cities, correlating them to the scores obtained during the reports. With the intention of quantitatively expressing the intensity of the relationship between two variables, a correlation is necessary to be calculated. A simple correlation both for the provincial level and for that based on provincial capitals verified whether there is a relationship between indicators, demonstrating their inclination to change together. In this way, indicators allow to investigate the Italian country through an exhaustive socio-economic, environmental and energetic description, providing an extensive clarification on their sustainable development and performance in recent years.

The economic and social spheres are essential for an innovative territorial context. Results demonstrated that the smartest contexts are those that are positively correlated with the youth employment rate, people with high professionalism and with advanced educational qualifications, income per capita, heterogeneous society (foreigners, mixed couples) and high mobility, at the provincial level. While the lack of interest in the formation and education, high scores of employments in occupations with low skill levels and spatial immobility do not emerge in the virtuous contexts. Furthermore, results demonstrated that the indicators of "Olives to produce table Olives and Oil / Woody Agricultural Crops" and "Family Gardens / Population" highlight a land-use that is not present in the smartest territorial contexts.

Figure 6.1. demonstrates, with dots, the average values obtained from reports by Italian cities, in terms of smart cities. Larger dots are concentrated in the north Italy, in addition to other major cities such as Florence and Rome. “SAU/OCC AGR” indicator assumes higher scores in the central areas and on the major islands, where the rural landscape and the relative agricultural employment are significant. The second map (for EIAGR) confirms this assumption, giving relief to the southern and central contexts. As already mentioned, the early exit from the education system is a worrying phenomenon especially in the south, despite assumes average values also in other areas of Italy. Higher incomes are concentrated in the northern areas, decreasing towards the south and accentuating only in the most important cities. This finding allows to reflect on the role of the socio-economic sphere that influences directly the classification concerning smart cities.

The correlation also considered indicators at the provincial capital scale for investigating on environmental, mobility and energetic characters. Such analysis reveals other considerations. Smarter cities are double-edged realities. Although they produce a high rate of waste (compared to the population), separate collection of municipal waste is more consistent. The demand for public transport is high, representing a necessary requirement for starting smart contexts. Yet these contexts are the most consumers and energy-intensive. First, especially in the domestic environment, the electric and gas consumption per capita is the highest. Second, despite a high number of vehicles, there is an evident presence of natural gas vehicles and the strong demand for public mobility (in which, in time, there has been a decrease in the choice of private vehicles and vehicles with higher emissions as gasoline). Third, they are more lighted areas (that refer to possible security reasons).

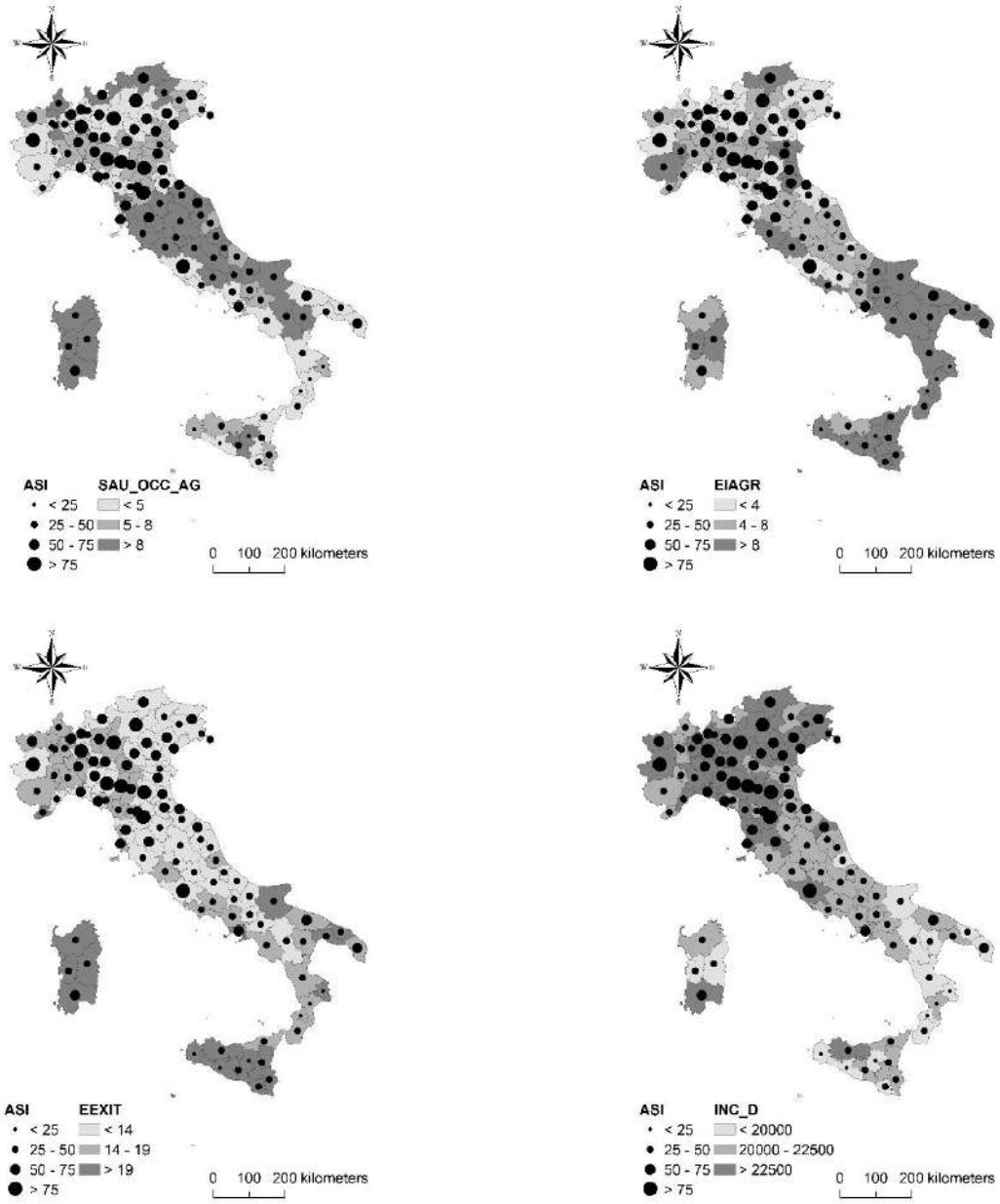

Figure 6.1. The average score of smart cities (ASI, expressed in dots) and relevant indicators, that are "Utilized Agricultural Area / Employed in Agriculture" (SAU/OCC AGR), "Employment incidence in Agriculture" (EIAGR), "Early Exit from the Education and Training System" (EEXIT) and "Average Income / declarants" (INC/D).

6.2. Towards rural smart solutions

The establishment of smart cities depends strongly on the local configuration. Technological innovation, active society and dynamic economy, synergies that increase progress, citizens adapting sustainable behaviours (e.g. as a high amount of natural gas cars or separate collection of waste) are all prerequisites that increase the 'smart' degree. Excluding large cities such as Rome, central and southern contexts, given their agricultural tradition, occupy the last positions of the report rankings. The inertia of inhabitants in mobility or training / education weighs on the degree of innovation of these areas. The need to define strategies and policies is essential. Agro-energetic districts represent a real opportunity for southern and central realities, with the purpose of strengthening and

improving their socio-economic structures linked to technological innovation, sustainability and environmental - landscape quality, reducing waste.

Biomass utilization is considered as a support for enhancing the development of rural areas (FAO (2000) Bioenergy. Committee on Agricolture, Rome, 13-16 April). Even if the degree of sustainability of the agro-energy supply chains has to be evaluated, their analysis is interesting as they can be considered networks of production processes, such as cultivation, biomass production and energy conversion, which transform inputs into outputs (Albino et al., 2007). Biomass have various origins (obtained from natural, forestry or agricultural sources), for e.g. thermal power stations (greenhouse crops), photovoltaic equipment in farms and production of biodiesel and biogas (Frayssignes, 2011). Despite certain issues, the perspectives offered by the agro-energy sector could become an additional factor for the improvement of the competitiveness and sustainability of agricultural areas, as a possible institutional construct of the Mediterranean governance of rural development (Frayssignes, 2011). According to the local environmental sources, agro-energy supply chains permit to gain motivated goals of energy production, even in those countries that do not use enough renewable sources (Albino et al., 2007). Hosting agro-energy activities can provide local solutions in terms of technology, organization, economy and sustainability (rural development, sustainable agricultural management, conservation and climate change mitigation) customized for the production and use of energy from agriculture (Best, 2003; Manos et al., 2014). Such districts assign also an energetic role to agriculture, contributing to the socio-economic and environmental sustainability at the different scale (from global to local level) (Rosillo-Calle, 2003). In fact, from the economic point of view, agro-energy districts can give benefits to the development dynamics in rural areas (Frayssignes, 2011). Job opportunities are one of the main advantages, due to the many multiplying effects which help to activate and strengthen local economy (Rosillo-Calle, 2003). Given the dependence of modern societies on fossil fuel sources and the emergence of sustainable attitudes, agro-energy sector permits to interact and develop synergies lowering production costs, enhancing and improving the quality (both ecological and of life of the relative inhabitants) in rural areas (Manos et al., 2014; Frayssignes, 2011; Best, 2003). According to Frayssignes (2011), agro-energy districts intended for urban areas satisfies a desire for social cohesion between territories (balance between towns and countryside). The transformations of society (e.g mobility of the population, modern economic activities) have questioned the relationship between town and country, (Perrier-Cornet, Aznar, Jeanneaux, 2010). Envisaging rural developing through agro-energy activities means analysing agriculture as a fully-independent renewable energy supply sector. A consequential socio-economic development of rural areas incentives a significant positive contribution to the environment and sustainability (Rosillo-Calle, 2003; Albino et al., 2007). According Tenerelli and Monteleone (2008), the crop classification approach underlines the potential effects that the choice of the energy crops mix may have on the environment in terms of land conservation and management of the natural resources. Energy crops contribute to obtain positive effects on the environmental in terms of land conservation and management of the natural recourses. Spatial analysis is necessary to assess the environmental and natural system.

Agro-energy supply chain bases its relations with the territory through the circularity of the production process (Albino et al., 2007). Wastes of agriculture, forest and their relative transformation industries (or plants completely dedicated to energy production) compose the raw materials. In this way, the majority of output return to the territory (Itabia, 2003). The development

of agro-energy activities generates a socio-economic cycle, in terms of attraction of financial flows, development of local skills and introduction of new business activities, that allow innovation and virtuosity. Furthermore, intensive farming activities are less required thank to the presence of energy plants, consenting to maintain organic substances in the soil without increase CO2 release in the atmosphere (Gallia and Pampana, 2004).

The respect, protection and conservation of the territorial connotations should not be seen as a weakness, but it must be considered as an opportunity. Adapting new models, such as circular economy and agro-energy districts, new micro-economies allow an increase of innovation, employment, stimulus, sustainable development and environmental quality. Proposing a reading approach of the reports of smart cities towards the identification of chances designated for the most disadvantaged backgrounds, latent solutions emerge that allows to strengthen the economic system, embracing an idea of respect for the natural- rural environment.

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7. Exploring contemporary context with GIS technologies

Information technologies are now established in the processes of analysis, planning and land management through the increasingly widespread use of Geographic Information System program (GIS). This technological innovation is destined to transform in a short time the way of conceiving the processes of knowledge and territorial intervention. In fact, it improves and accelerates (i) the knowledge as evolution of the concept of technical and thematic cartography, now conceived and structured in terms of information technology and no longer just paper; and (ii) the involvement in relation to the generalized introduction of methods of assessment of environmental and territorial resources, based on indicators of a parametric type and on the overlap of thematic plans implemented. Moreover, the GIS tool is like a planner of a sort of territorial historical memory, which can be continuously updated. This is particularly useful for the rural territory, where the dynamics of the current transformations, originated both by the new international policy scenarios and by the changes in housing and production models, are destined to profoundly change the organizational structure and the ecological-landscape structure of the agricultural and forestry systems.

GIS programs, particularly ArcGIS (ESRI Inc., Redwoods, USA), were strongly used since they were usable during the research and analysis activities to highlight different issues: demographic, socio-economic, environmental, land use changes, especially rural and natural land use and even energy aspects as well as identifying the degree of safety in the workplace. Therefore, GIS can also produce valid agro-technological assessments and multifaceted examinations of rural fields (Pecze et al., 2001).

7.1. GIS application combining agricultural and energy purposes

Greenhouse activities are relevant for the Italian agriculture owing to their production quality and technology development (Marucci et al., 2014). In Italy, with the rise of photovoltaic (PV) technology, the expansion of solar greenhouses led to a diversification of the agricultural production, energy efficiency and farmer's specialization (Carlini et al., 2012). The extensive availability of surfaces guaranteed by greenhouses (and farm buildings) can be used to install PV systems promoting a new sustainable profile for agriculture (Tudisca et al., 2013; Sgroi et al., 2014). The political support of PV modules would assist the regional progress by creating new job opportunities and supporting entrepreneurs' income (Schuetze, 2013). However, the elevated financial profits from PV energy production on greenhouses will exist until conspicuous public subsidies are available (Cossu et al., 2014). Preventing a new decline of the primary sector, a set of tools and strategies must be planned with the aim to avoid conflicting and challenging realities. Unfortunately, the legislative sphere does not help to reply to that question. In Italy, regulations for greenhouses are devoid of a national law in terms of land, structures and equipment (Bianchi and Sancilio, 1992). Greenhouses are regulated at the regional or municipal level with discretionary restrictions imposed by local authorities and technicians (Scarascia Mugnozza, 1995). With PV trend, national and regional administrations have planned several limitations useful to prevent speculative episodes regarding PV greenhouses (GSE, 2014).

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Zambon, I., Colantoni, A., Monarca, D., Cecchini, M., Marucci, A., Piacentini L., Feltrini, S. (2017). Greenhouses Plants as A Landmark For Research And Innovation: The Combination Of Agricultural And Energy Purposes In Italy. Xxxvii Ciosta and Cigr Section V Conference 2017 - Palermo, Italia, 13 - 15 June 2017.

Furthermore, PV systems can be considered as an everyday infrastructure in the Mediterranean landscape of Europe (Delfanti et al., 2016), as in Italy, where their diffusion has increased rural multi-functionality (Tudisca et al., 2013; Marcheggiani et al., 2013). However rural land has been designed to a non-agricultural function but an energy purpose (Marcheggiani et al., 2013), leading to an increasing rate of soil sealing and degradation, landscape deterioration and other speculative actions (e.g. Delfanti et al.,

2016). To deal with this situation, since 2013 governments have promoted the realization of PV systems integrated into existing structures (such as greenhouses or farm buildings) rather than on the ground (GSE, 2014; Castellano, 2014). PV panels installed on greenhouses can be a solution (Tudisca et al., 2013), appeasing the debate on the intended land use, especially in the long term, because they do not subtract agricultural soil without compromising its quality and fertility (Sgroi et al., 2014).

Given such background, the present work aims to give new research inputs and actionable progress actions based on virtuous projects that have already combined greenhouses and energy from renewable sources. Greenhouse plants can be considered a local landmark that indicates where advantages and disadvantages coexist in a specific area. However, their study, as economic and local landscape indicator, is underdeveloped in Italy. Nothing has been done to evaluate PV greenhouse plants as a part of the agricultural landscape with a potential energy, due to restricted database and very local research studies (e.g. Sgroi et al., 2014; Tudisca et al., 2013).

Based on the contribution of other countries (e.g. Spain and the Netherlands) in which greenhouses are relevant for spatial analysis, the lack of opportune tools is a continuing obstacle to investigation and innovation in Italy. The requirement to build a database with the help of new technologies (such as GIS) may characterise a real opportunity that implements research, spatial planning (in order to prevent environmental - natural risks and to know which crops are present in a local area), policy making and for calculating energy efficiency from renewable sources installed on greenhouses.

7.1.1. Identification of greenhouses plants

The area studied covers the entire Italian national territory (301,330 km^2), subdivided into 20 regions and 8,092 municipalities. Although its coastline (counting islands) extends nearly 7,400 km, most of the continental land is hilly or mountainous. Topography, latitudinal range and proximity to the sea coast have had a great influence on local climate, soil, vegetation and landscape (Salvati and Bajocco, 2011). Thanks to its favorable geographical position and climatic features, greenhouse structures and PV fields have been widely dispersed along the country, identifying a relevant production quality and technology progress (Marucci et al., 2014).

Italian available databases are disposed by the National Institute of Statistics (ISTAT), which reported statistics regarding the vegetables produced in greenhouses for each year, defining the total area (hectares), area in production (hectares), the total production (tons) and the harvested production (tons).

PV plants installed in Italy can be derived from the Atlasole database provided by the Italian Energy Services Manager (GSE) by municipality and plant power. For each administrative region, the surface area of rural land occupied by PV fields was provided by GSE (2014). Plants were classified by installation support (e.g. ground, building or greenhouse roof, infrastructures). The total surface area of PV fields (m^2) was provided separately for each region, together with the number of plants and their total power (MW) through GSE annual statistical report.

Currently geo-referenced elements of greenhouse and PV structures do not exist for Italy. Existing available spatial data are limited to local-scale study contexts (e.g. Sgroi et al., 2014; Marucci et al., 2014; Tudisca et al., 2013; Pérez-Alonso et al., 2012; Sönmez and Sari, 2007).

The main studies that have focused on greenhouses concern two European contexts: Almeria region (Spain) and the Netherlands. Almeria, situated in the south-east of Spain, is considered the context with the highest concentration of greenhouses in the world (Molina-Aiz et al., 2004). Also, the Netherlands are famous for their production of horticultural products in greenhouses. An open source is available on the website of the Netherlands government, where is possible to found data also on the spatial distribution of greenhouses. The latter, in shape file format, has consented to spatially investigate on greenhouse

structures, identified at the local level, reporting for each item different information (e.g. current status, surface area). This information is useful to understand the degree of spatial distribution and occupation of greenhouses in the Netherlands, even if currently a detail data of PV systems has not been implemented.

In Italy, a similar database and spatial data to those of the Almeria region and the Netherlands does not exist. Based on the experience of these two contexts, taken as reference points, in the present work the data collected were integrated with maps of land use (Corine Land Cover) and soil sealing available from the Copernicus Programme, using the GIS program in order to advance a spatial reflection.

7.1.2. Greenhouses plants as a landmark for research and innovation

The distribution of PV systems on greenhouses and their energy production pointed out on a regional basis that Sardinia, Sicily and Puglia are those with higher values of PV greenhouses (GSE - statistical Report 2014) (Table 7.1).

Table 7.1. Situation of PV energy on greenhouse plants. Source: own elaboration from GSE, 2014.

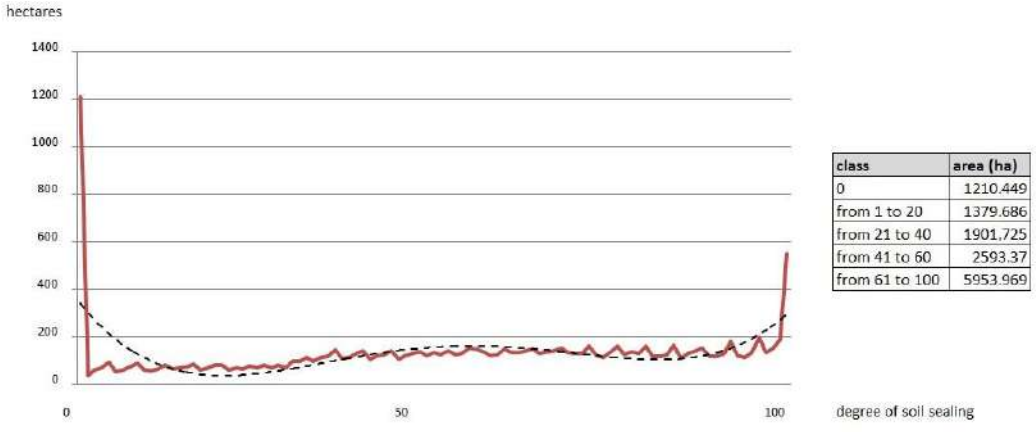
Region	MW	Gross irradiation (h)	Net radiation (h)	Production (GWh)	Number Practices*	Power (MW)*	Power greenhouse/ PV Power
Abruzzi	14	1630	1278	18	8	2.28	6.1
Basilicata	18	1790	1403	25	17	11.22	1.6
Calabria	94	1730	1356	128	120	72.90	1.3
Campania	35	1690	1325	46	54	12.61	2.8
Emilia Romagna	56	1430	1121	63	69	26.14	2.1
Friuli Venezia Giulia	10	1470	1152	12	10	1.00	10.0
Latium	84	1680	1317	111	43	36.27	2.3
Liguria	17	1560	1223	21	156	12.72	1.3
Lombardy	62	1470	1152	71	48	21.35	2.9
Marche	31	1660	1301	40	27	10.15	3.1
Molise	5	1710	1341	7	5	1.31	3.8
Piedmont	45	1560	1223	55	65	27.66	1.6
Apulia	102	1820	1427	146	98	36.61	2.8
Sardinia	200	1840	1443	289	86	162.15	1.2
Sicily	168	1870	1466	247	373	116.65	1.4
Tuscany	37	1540	1207	45	19	2.08	17.7
Trentino Alto Adige	8	1390	1090	9	24	2.52	3.2
Umbria	27	1600	1254	34	12	3.15	8.6
Valle d'Aosta	0	1600	1254	0	0	0.00	0.0
Veneto	69	1460	1145	79	66	26.04	2.6

* with electricity accounts. The number of practices means how many PV plants have been authorized indicating the corresponding power.

Data regarding Italian context are limited to only give a statistical information, without geo-referenced items. Consequently, the work was oriented to analyze and examine the Dutch spatial data that identifies a total of 13,897 greenhouses occupying about 34,000 hectares (Figure 7.1). Overlaying with the Corine Land Cover (CLC) map, greenhouses are mainly concentrated in agricultural areas (96.3%) highlighting a strong relationship between greenhouses and the rural context.

Figure 7.1. Satellite image shows a context with high concentration of greenhouses (left); inserting the vector data of greenhouses (right) (Source: own elaboration).

In addition to CLC coverage, the examination was continued by assessing how much greenhouses impact in terms of soil sealing rate. The spatial greenhouse vector was superimposed on soil sealing mapping, always available in the Copernicus site. From an initial analysis, most of the surface area occupied by greenhouses exists in an environment with the value '0', devoid of soil sealing (usually intended for agricultural use). Polynomial trend line was used for trend analysis, based on test and error method for several orders of polynomial fitting and the resultant correlation coefficients (Mohan et al., 2011). A polynomial line showed the tendency of the land occupied by greenhouses according to the degree of soil sealing (figure 7.2): it decreases and grows, reaching high values for degrees of soil sealing equal to 0, 50 and higher scores. This data was checked by aggregating soil sealing rates into five classes ('0' for non-permeable soils, from '1' to '20' low sealing, from '21' to '40' medium sealing; from '41' to '60' medium-high sealing; more than '61' highly impermeable soils). Greenhouses on soil sealing equal to 0 are only 9% (occupying only 1,210.4 hectares), if they affect the highest class (61-100), occupying a surface of 5,954 hectares. In conclusion, in area terms, the coverage of greenhouse plants leads to a strong degree of soil sealing and therefore an impact on the soil component. Results revealed a first reflection on the environmental impact that greenhouses may determine and, for that reason, the importance of having spatial data is crucial to examine a district at a detailed scale.



class	area (ha)
0	1210.449
from 1 to 20	1379.686
from 21 to 40	1901.725
from 41 to 60	2593.37
from 61 to 100	5953.969

Figure 7.2. A polynomial line indicates the trend of the degree of soil sealing (x-axis) and the surface occupied by greenhouses (ordinate axis), explaining the surface area intended for greenhouses on the soil sealing classes. Source: own elaboration.

For Almeria, the available studies have focused on the local level and a global greenhouse (and PV) data does not even exist in Spain. The province of Almeria highlights a strong presence of greenhouse plants (Figure 7.3, circled in red). However, according to Corine Land Cover, the whole area is dedicated to agricultural activities (Figure 7.3). Only an overlap with the imperviousness map brought out the impact

on the soil component. In fact, the highest rates of sealing are recorded exactly where there is the strong concentration of greenhouses, with values greater than 60 (like those of an urban environment).

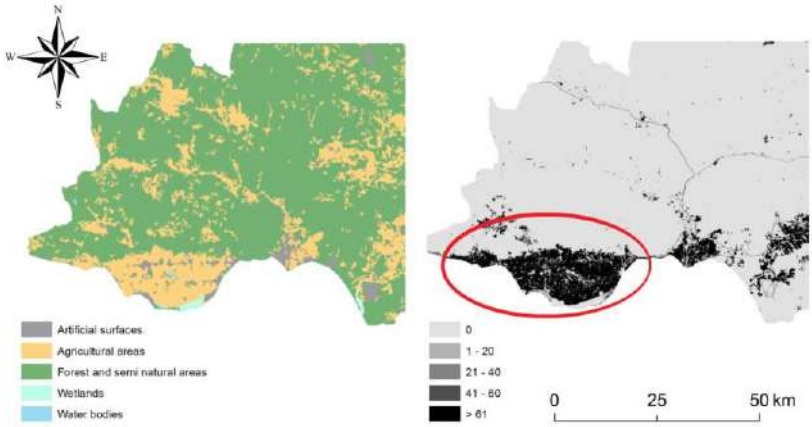


Figure 7.3. Focus on CLC (left) and soil sealing map of the Southern part of Almeria, indicating the strong concentration of greenhouse plants with a red circle (Source: own elaboration).

7.1.3. Importance in using spatial landmarks

Greenhouse plants have become more concentrated in several regions (Badgery-Parker, 2005), as Italy, Spain and Netherlands (Rogge et al., 2008). The reflection that emerges from this work is significant to define the role of greenhouses at spatial scale. While greenhouses allow profitable agricultural activities (Sönmez and Sari, 2007), they implicate a high soil sealing and a consequential risk to land degradation processes (Colantoni et al., 2015). A potential alternative in contexts with a strong concentration of greenhouses can be to integrate them with PV systems, leading towards a more sustainable development of an area (at least from an energy point of view) and avoiding the use of agricultural land for ground-mounted PV fields. As noted by the results emerged from the spatial analysis regarding the Netherlands, the territorial distribution of greenhouses can be considered a useful landmark which concerns an entire country at a very accurate scale, even if its greater integration with PV data would give more insights. However, it represents a methodological model to follow in order to build a spatial database of (PV) greenhouses in Italy.

Our study aims to reflect on the lack of application and methodological tools in Italy, demonstrating a progressing obstacle to research and innovation. The importance of having a statistical and spatial database about greenhouse and PV plants at a detailed level on a national scale (as for Netherlands) enables the prediction of further damage, a constant monitoring of an area both in economic, environmental and energy terms, a series of actions and policies planned in order to prevent future negative impacts and manage effectively the territory. The detection and localization of greenhouse plants represents an important chance for policy-makers and other stakeholders in order to take the appropriate decisions on the territorial and resource management (e.g. energy) (Carvajal et al., 2006). Continuous monitoring must be guaranteed by means of the GIS programs by collecting, processing, retrieving and displaying spatial data (Burrough and McDonnell, 1998; Rogge et al., 2008), combining and integrating them to produce information (Lee et al., 1999). The existing studies emphasize that GIS elaboration can support policy-makers in addressing key issues (Peccol et al., 1996) and to take effective decision-support systems that deal with the territorial planning (Bryan, 2003). The originality of this work is based on the need to build spatial databases, at national level, able to offer new research developments in Italy. Greenhouses (and PV systems) can represent reliable territorial landmarks that better describe contexts, with the purpose of studying, analyzing and evaluating its sustainable development (from a national to a local level) in economic, environmental, energy and landscape terms.

7.2. The role of precision agriculture

Precision agriculture has provided a remarkable positive contribution to the primary sector globally at various levels (Zhang et al., 2002; Florax et al.,2002; McBratney et al.; 2005; Pretty et al., 2010). Unlike conventional agricultural methods, it can adapt crop yields by considering the local variability of the physical, chemical, and biological characteristics of soils, as well as the application time through the development of technological and computer support (Berti, 1994, 2000; Pierce and Sadler, 1997). Precision agriculture employs machines equipped with "intelligent systems", which can measure production factors in relation to the real needs of a plot and of different homogeneous areas within it (Verhagen and Bouma, 1997). According to (Robert, 1993), several goals can be achieved, such as: (i) enhancing yields with the same total inputs; (ii) reducing inputs with equal yield; (iii) increasing yields by reducing inputs at the same time. Furthermore, when applied to conservative soil methods, the principles of precision agriculture can (i) maintain environmental benefits, (ii) improve corporate income, and (iii) rationalize the use of machines (Bongiovanni and Lowenberg-DeBoer, 2004; Adamchuk et al., 2004).

Analyzing precision farming from environmental, economic, and management points of view, several positive impacts emerge, which should not be underestimated (Bongiovanni and Lowenberg-DeBoer, 2004; Auernhammer, 2001; Stafford, 2000; Oliver et al., 2013). Focusing on economic benefits, an overall optimization of crop interventions can be detected, together with a quantitative reduction of distributed chemicals (Stafford, 2000) and an improved operational and safety capacity for operators in their workplace. It should also be stressed that the above-mentioned economic benefits can also be derived from two reasons: firstly, for the probable growth in costs of the production factors; secondly, on the other hand, for the likely reduction in the cost of purchasing technical equipment, which occurs as demand and technological evolution rise.

Cited article

Marucci, A., Colantoni, A., Zambon, I., Egidi, G. (2017). Precision Farming In Hilly Areas: The Use Of Network Rtk In Gnss Technology. Agriculture 7(7), 60.

7.2.1. Examples of sensors in rural environment

The modern approach to precision agriculture is based on flexible customized and equipped technology solutions with extensive interoperability. This method is essential as it can manage the wide variability of usage conditions in typical Italian farms, which are characterized by their (often highly fragmented) land capital (Lund and Hill, 1979; Van Dijk, 2003; Alvarez and Arias, 2004; Gorton and Davidova, 2004; Galluzzo, 2015). The diffusion of highly-innovative techniques, favored by their adaptability to each agricultural reality, would substantially contribute to the modern transformation of productive processes in the Italian primary sector (Pisante et al., 2012). Nowadays, the use of a service platform for product data capture related to production is widely available in several areas through local devices. The latter include sensors, automatic guidance systems with Global Navigation Satellite Systems (GNSS), and central processing systems. Specifically, GNSS technology, as a European global navigation satellite system, ensures greater positioning accuracy and reliability compared to GPS, as it is designed to provide real-time positioning services (Spiller et al., 1999; Divis, 1999; Crespi et al., 2012). The use of the signals of GNSS was initially anticipated in the late 1980s (Sánchez et al., 2015; Hall et al., 1988) and experimentally confirmed in the early 1990s (Auber et al., 1994). Regardless of this initial approach to GNSS techniques, the initial efforts to evaluate soil moisture from reflectivity dimensions arise in 2003 (Zavorotny et al., 2003). GNSS, such as the Global Positioning System (GPS) technology, has grown and developed as a controlling atmospheric remote sensing tool able to provide precise observations of atmospheric parameters. The success of GPS has stimulated additional progress of GNSS technology. Nevertheless, these two systems can be defined as complementary (Choy et al., 2015). An additional value of these kind of technologies is that they can perform in all weather conditions. This feature of GNSS offers useful

information also during cloudy and rainy days, which are still uncertain blocks to radar systems and low Earth orbiting satellites (Awange, 2012).

Potential technical enhancements must be set in the background of processing power and sophisticated technology previously incorporated into GPS receivers (Stafford, 2000). These devices (as GNSS technology) permit land mapping. Through the latter, a geo-referenced data survey, allows observation of the characteristics of the field to be cultivated (e.g., size and perimeter) and defines subsequent planning phases. An information flux between rural machines and the farm's management can be performed. In this way, through these devices, it is possible to optimize automation with vehicles, which can repeat (or exclude) a path already done. Lastly, an appropriate technical analysis points out (i) the enhancement points and agronomic practices to be implemented or, simply, (ii) a unique business database reporting the surfaces of the cultivated areas and the activities carried out on them.

GNSS technologies can rapidly get involved when critical events emerge due to a specific incident or agent. This smart advice could a save of products and reduce environmental impact, without (i) having to maximize the use of technical vehicles (e.g., seeds and fertilizers) and (ii) taking account of the tangible need for crops or the (qualitative and quantitative) presence of weeds. Even if these techniques are mainly spreading in flat areas, increasing attention to site-specific management in precision farming is emerging in hilly contexts (Wu et al., 2011). In the latter areas, precision agriculture continues to be very limited due to the effort required during the assessment. Hills can be a relevant cause for missing observations (Brown et al., 2007). One of their main limits is the highest error probability, even where hills are small, compared to the flatter regions (Crespi et al., 2012; Ressl et al., 2011).

The positioning system (as GPS) can continuously record both the in-field and the correct position of a vehicle in use (Neményi et al., 2003). All the collected data can then be processed through a Geographic Information System program (GIS). Measuring the effective distribution of such systems in less-favored areas, a project was carried out under the rural development program (RDP) in the Lazio Region 2007/2013 measure 1.2.4. The latter aims to assess financial farming conditions. European support might be granting merely the supplementary financing needed to implement the project in more attractive farms (in terms of local sources or banking system) (Dono and Ceccarelli, 2010).

The experimental activities envisaged in the project concerned: (i) the employment of a permanent station network (Network RTK), exportable as a connection model to other users, (i) improving the efficiency of applications in precision agriculture and (ii) exporting processing data in the areas (to be tested) in a corporate GIS program; (ii) the execution of experimental assessments on defined areas, evaluating how to reduce the use of technical vehicles in three different ways of driving (manual, assisted, automatic); and (iii) the identification of areas with special orographic constraints, using the GIS program, sending warnings to operators both at entry and exit from the area, and even in cases of excessive inclination of the vehicle during its use (avoiding potential risk of overturning).

7.2.2. Execution of experimental tests

For the execution of experimental tests (at the stage of weeding), three farms have been identified. Achieving the main purpose, a homogeneous environment was chosen for the selected farms, where only one seasonal crop was present (wheat). The three farms are representative of the agricultural reality in Tuscia. The territory of Tuscia is an area that often coincides with the province of Viterbo, located in the central part of Italy. The satellite-navigation systems have been installed on all the vehicles of the selected farms, including an electric steering wheel, control monitor, and GNSS antenna. In these instruments, calibrations were performed for automatic guidance and configuration for the network connection of permanent RTK stations. The network of permanent RTK stationary stations was developed for the distribution of differential corrections for geodesy and topography, enable the performance topographic

surveys with only one receiver connected to one of the available networks.

This technology and methodology, if used even in precision agriculture applications, can: (i) avoid installing and using the "base", where it is possible to operate with only one receiver on the vehicle; (ii) operate across the area covered by the network and border areas, without having the problem of distance from the reference station, always with the same position precision; (iii) gain greater system reliability and integrity, due to the systematic error management resulting from the overall network calculation; (iv) dispel all doubt and ambiguity compared to the traditional RTK technique; (v) know the spatial position of the vehicle in a single and controlled reference system; (vi) have a high degree of repeatability, over time, both of the positioning and operation of the vehicle; (vii) receive distribution across the internet (NTRIP protocol) of differential corrections; and (viii) operate in areas with low GPRS/UMTS coverage through local solutions (RTK Bridge). Differential correction occurs via the Virtual Reference Station (VRS), whose operating principles are: (i) the receiver on the agricultural vehicle estimates its approximate location (error of a few meters) through the GPS and GLONASS satellites only and sends it to the control center thanks to the active connection of its modem; (ii) the control center generates a dedicated (virtual) base station for the potential user and sends differential corrections in real time; and (iii) the receiver on the agricultural vehicle corrects its estimated position with the data sent by the network and achieves a centimeter accuracy.

The subsequent experimental activity concerned the evaluation of reducing the number of technical vehicles employed. Such activity, envisaged for an entire crop cycle, was addressed to every single agronomic practice from soil preparation up to harvesting. The test area extends over as surface of approximately three hectares, divided into three equal portions, following their physical and geo-morphological characteristics. By way of example, the results in the next paragraph are related to the weeding operation. This choice is surely one of the most beneficial activities from satellite navigation systems. The transaction data was recorded and downloaded from the system for consequent analysis. The execution times for each individual processing have been scheduled, by tracking the consumption of the product used and verifying the correct functioning of the satellite system in the intended modes of use. During the tests, three driving systems were verified: manual, assistive, and automatic.

In the first mode, cultivation operations were carried out by an operator without any technological aid. In this case, the system recorded only the path of the machine and other technical data (e.g., position, time, feed rate, path). In the second mode, the same operations were carried out using the assisted guidance GNSS system. In this situation, the operator was facilitated more by the onboard computer system. The latter reported the path and the deviation from the trajectory to be followed in a monitor/video. The third mode involved the implementation of a total automation processes. The tractor followed specific paths, defined on a map, through the automatic pilot. The operator was limited to monitoring the correct operation of devices and operating machines. This compares the traditional operating modes with precision agriculture, in terms of products used, execution times, and job safety. The reduction of environmental emissions into the atmosphere and the inadequacies in the implementation of agronomic practices were also assessed.

Regarding the latest research goal, a fleet management device was not immediately visible from the cabin (as it is an alarm device in case of theft). The system has many configuration options and functions, as well as serving as an aid to the management and maintenance of the vehicle itself. It is also possible to define a "limit zone" in the system: if the vehicle exits or enters this area, at uninterrupted time intervals, even when the engine is off, the device sends SMS or e-mail alerts. For areas with poor Internet coverage, a device called an RTK-Bridge has been tested (Figure 7.4). The device was placed in an area where there was a low Internet coverage. It has been connected to the permanent station network, sending its approximate position. It downloaded the differential corrections and then redistributed all the media

operating through a low power radio. The width of the radio coverage depends on the territorial profile and the presence of obstacles. Like all radio devices, it is better to place the device at the highest point of the working area. In addition, for increasing operator safety, a device has been tested to send alarms via SMS and to switch on an led in the cabin, when one or more previously set inclination values of the vehicle have been reached. Two limit corners were set (a first angle of 15° and a second one of 45°). This latter angle greatly exceeded the safety limits for crawler tractors, and thus represented an alarm for probable overturning of the vehicle.

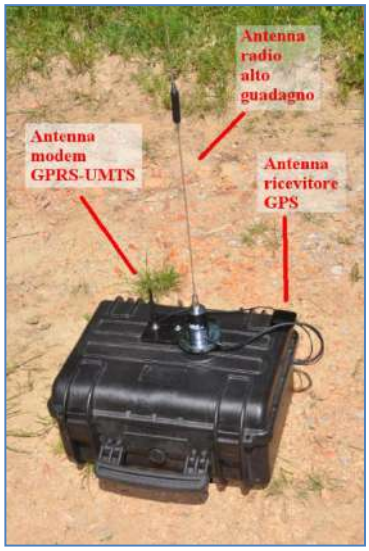


Figure 7.4. RTK-Bridge device.

7.2.3. Results using Network RTK in GNSS Technology

The experimentation for the use of permanent stations in precision agriculture has achieved several significant results. It showed that (i) the correction sent by permanent stations via the Network RTK to the GNSS system, concerning the vehicle in motion, was uniform and then (ii) the degree of precision varied with respect to the satellite constellation, visible during use and according to GPRS coverage, with which the system connected firstly to the network and then to the server. The system has changed, passing from "FIXED" (the system is connected to the network and receives a centimeter-accurate correction) to "FLOAT" (connected to the network but receiving a sub-metric precision correction) or to "STD" (the system is not connected to the network and collects only satellite correction with metric accuracy). However, the system can maintain the predetermined trajectory of the agricultural vehicle for a few seconds and then it emits a warning alert due to the loss of centimeter accuracy. This allowed us to assess whether the loss of precision was owed to a reduced GPRS signal or to an insufficient satellite constellation. Therefore, it is possible to act accordingly. It is necessary to wait (i) for the satellite signal, which allows a calculation and correction with the "FIXED" solution, or (ii) for the automatic system reconnection to the server. In addition, all data concerning the work carried out from the selected representative farms has been performed in the GIS program. A map about the treated terrains for each individual processing can be achieved. The resulting map quantifies the size of the operational surface areas for subsequent treatment scheduling. This management method allowed a seasonal check of the tasks that need to be performed and a planning of crop operations based on business choices achieved with the help of the GIS system.

Considering the three driving methods (manual, assisted, and automatic), experimental examinations on test areas checked the incidence of the human factor in the management of normal agronomic practices. Several benefits derived from new technologies, optimizing production and ensuring decreases in production times, environmental impacts, and fuel consumption.

The comparison between traditional operating methods and those tested with precision agriculture revealed significant progress, comparing the three driving methods.

The steps of the agricultural vehicle during the action of weeding are shown (bar 12 m). The GNSS system graphically represented the positioning of satellite acquisitions along the path followed by the tractor. The assisted and automatic guidance systems allowed a more homogeneous soil treatment compared to the manual one. The covered surface was much more homogeneous, with the almost total disappearance of untreated areas and overlapping areas. All this is accompanied by a high driving comfort and better ease of execution during the operational activities.

The data for the activities carried out during the experimental field tests are shown in the Table 7.2. The cultivation operations concerned: (i) the soil preparation by 30-35 cm deep plowing carried out at the end of August without the GNSS system; (ii) fertilization, assuming GNSS aid; (iii) harrowing for the preparation of the sowing bed carried out in mid-November, without the GNSS system; (iv) sowing, following harrowing, with a seed density of about 300 kg/ha, without the GNSS system; (v) phytosanitary treatment, with chemical and fungicide weeding in mid-January; (vi) chemical weed control (ARIANE + AXIAL + activator) in February-March; (vii) chemical and fungicidal fertilization in April; collection of the product, with a grain yield of about 6 t/ha and 3.6 t/ha of straw, at the end of June-July, without the GNSS system.

Table 7.2. Primary data collected during experimental field trials.

	Type of Crop: Wheat				
			Manual	Assisted	Automatic
Primary data	Seeding density	kg/ha	300	257	254
	Grain yields	t/ha	6	5.1	5.1
	Quantity yield straw	t/ha	3.6	3.1	3.1
Cultivation operations	Plowing (30-35 cm)		August/September		
	Fertilization before sowing	Panfertil (Phosphate Biammonics 18-46) Dose: kg/ha	250	214	212
	Harrowing		November		
	Sowing		November		
	Chemical fertilization in January	Panfertil (Phosphate Biammonics 18-46) Dose: kg/ha	200	171	170
	Chemical disinfection + fungicide in January	GLEEN (kg/ha)	0.030	0.026	0.025
		Fungicida Zantara (Bayer) (l/ha)	1.5	1.28	1.27
	Chemical disinfection in February/March	ARIANE for wide leaf (l/ha)	3	2.6	2.5
		AXIAL for little leaf (l/ha)	1	0.86	0.85
		Activator (l/ha)	1	0.86	0.85
	Fungicidal chemical fertilization in April	AMIDAS urea (kg/ha)	200	171	170
		Fungicida Zantara (Bayer) (l/ha)	1.5	1.28	1.27
	Collection period	June/July			

In addition to a much better uniformity of treatment, significant reductions of products used should

also be noted over time. Different parameters were chosen: time spent during the operations (expressed in minutes); product used, i.e., products which are used during the operations of weeding (expressed in liters); rural surface area (expressed in hectares); and distance travelled, otherwise the length of the path carried out by the vehicle (expressed in kilometers). The parameters were then detected according to the three-driving controls observed. With the same coverage area and distance travelled, the time employed, and the amount of product used were considerably reduced in assisted and automatic guidance compared to manual driving. More specifically, time duration was reduced by 3.30% and the product used by 14.37% in assisted driving (when respectively they are 6.13% and 15% in automatic guidance). This result revealed that the transition from the assisted driving to the automatic mode did not affect the product used. For example, the overlapping or non-treated areas are almost non-existent in both modes. Instead, concerning the time spent, the automatic driving mode can be substantially preferred. The field tests carried out immediately provided divergent results, based on the parameters and the three driving types considered. For this reason, the data collected has not been combined even with statistical techniques.

Lastly, the introduction and installation of a telematic control system in common farms enabled the monitoring of their work and the performance of their vehicles. This can prevent risks in terms of unauthorized use of material goods, thefts, unplanned work, and unexpected movements. Above all, telematic control systems can constantly monitor the job conditions of workers, avoiding hazardous situations inside the passenger compartment on the agricultural vehicle. The test performed confirmed the correct operation of the device installed in all its operating modes. Utilizing this method of monitoring and controlling agricultural operations, any type of operational risk can be avoided, from theft and damage of agricultural resources, to greater dangers-without excluding the overturning of agricultural vehicles-with the possibility of saving human lives.

7.2.4. Precision farming in hilly areas

Despite an increasing awareness in hilly situations (Wu et al., 2011; Fu and Zhang, 2009), techniques for precision farming are essentially used in flat areas. One of the major problems of precision agriculture concerns the difficulty of properly monitoring and managing hilly areas due to the high probability of error and loss of important information during detection operations (Crespi et al., 2012; Brown et al., 2007; Ressl et al., 2011). This trouble can become critical if precision agriculture is applied to the Italian context. The latter presents a very varied territory, in which there is a strong presence of hillsides. Moreover, Italy has a fragmented rural landscape (Pisante et al., 2012), which may complicate territorial analysis operations. Few studies have focused and compared GPS and GNSS technologies, demonstrating their validity in hilly areas (Filip et al., 2000).

Attempts have been made to minimize possible errors derived from GNSS technology. Devices as GNSS technology permit land mapping, optimizing machining operations in which rural vehicles can repeat (or exclude) a path already done. The innovative element of GNSS technology is the opportunity of putting rural machines and the farm management in communication. This interaction allows a timely technical analysis that points out the degree of improvement, further agronomic practices that need to be implemented, or a unique business database containing all the surface areas cultivated and the activities carried out on them. All the collected data can be processed through a Geographic Information System program (GIS), allowing rural processes and suitable agro-technological assessments (Pecze et al., 2001). GIS and remote sensing are layer-based systems, giving their users the flexibility to superimpose different levels of reality and find the best model for more accurate agricultural practice. An interpolated map describing the soil type, slope, and aspect in hilly areas can simulate the yield of crops with various variety groups and other agricultural inputs. With specific devices (RTK bridge), it is possible to overcome any signal deficiencies. Finally, in rugged hilly terrain areas, using the satellite navigation system can safeguard operators' safety from potential risk concerning the overturning of agricultural vehicles.

7.3. GIS technologies for preventing job incidents in rural contexts

In recent years, job safety has been considered an emergent question in multi-disciplinary research across European countries (Colantoni et al., 2017). Several European countries have advanced well-defined regulations and policy strategies encouraging greater safety of operators and awareness of the potential risks which can emerge in distinct working sectors, such as in open-field activities (Colantoni et al., 2013; Cividino et al., 2014, 2015). For instance, several procedures on working places embody risky activities in agriculture and forestry, where serious injuries and fatalities can happen (Fabiano et al., 2004; Moreschi et al., 2014). Legal obligations and national guidelines for the safety of workers recognize the correct procedures for the correct use of machinery and tools (Cividino et al., 2012; Cividino, 2014.).

In the literature, quantifying job accidents is usually performed using classical methods and checklists (Marucci et al., 2013; Monarca et al., 2011), trying to register the most relevant information from each event, with the aim to identify and understand which factors interact together. For instance, the location where agricultural, forestry, garden maintenance and hobby activities occurred may outline several independent factors (e.g., environmental, geo-morphological): these drivers shape the overall exposure of a standard working operator and can even differ within different operators (Cividino, 2014; Marucci et al., 2013; Monarca et al., 2008, 2011, 2012; Bailer et al., 1997).

Cited article

Zambon, I., Piergentil, A., Salvati, L., Monarca, D., Matyjas-Łysakowska, P., Colantoni, A. (2018). Applied Research For A Safer Future: Exploring Recent Job Accidents In Agriculture, Italy (2012–2017). Processes, 6(7), 87.

Based on these premises, professional accidents occurred were detected in the last 6 years (2012-2017) in the primary sector, considering Italian administrative provinces as the elementary analysis' spatial domain. While earlier studies have proposed some qualitative and quantitative approaches to analyze job accidents (Bortolini et al., 2016; Colantoni et al., 2012; Lilley et al., 2002; Lindroos and Burström, 2010; Lindroos et al., 2008; Lundqvist and Gustafsson, 1992; Mann et al., 2010; Marucci et al., 2012; Monarca et al., 2009; Montorselli et al., 2010; Neely and Wilhelmson, 2006; Potočnik et al., 2009; Solomon et al., 2007; Suchomel and Belanová, 2009; Thelin, 2002; Delfanti et al., 2016), a better understanding of this complex issue is imperative today since agriculture and forestry has lost workers and relative land in recent decades (Monarca et al., 2008, 2011, 2012; Bailer et al., 1997; Cecchini et al., 2018). Today, agricultural land loss and abandonment, deforestation, excessive rate of land consumption and soil sealing are some of the foremost European challenges (Duvernoy et al., 2018; Marucci et al., 2018; Zambon et al., 2018, 2018; Colantoni et al., 2015), possibly influencing safety conditions for agricultural jobs. The need to valorize the primary sector is thus pertinent for endorsing and preserving natural and rural landscapes (Colantoni et al., 2015, 2016; Munafò et al., 2013; Pili et al., 2017; Salvati, 2014; Salvati et al., 2016; Cecchini et al., 2018), guaranteeing working safety at the same time (Purschwitz, and Field, 1990; Feltrin et al., 2015).

Conceivable scenarios can be explored following risk factors and operating conditions at different working sites with the aim of establishing suitable technical, legislative and operational suggestions (Moreschi et al., 2014). Some current studies focused on explicit issues that can be correlated with high-risk agricultural and forestry operations. First, courses and training in occupational safety should be planned and structured by employing definite class and practical models that suggest new and more advanced strategies promoting a safe working environment (OECD 2002). Second, the 2007 economic crisis and a worse-performing job market determined the increased fixed-term (or temporary) contracts in the European countries, especially in the ones most affected by economic recession, e.g., Mediterranean Europe (Hernanz et al., 2006). With such background, temporary employees are often less practiced and unaware of risky operations. The widespread application of provisional work has raised worries about increased volatility of employment and the relative consequences for job quality and working conditions

(Cecchini et al., 2015).

Third, farming and forestry subdivisions offer cheaper and fixed-term (often illegal) occupations to foreigners (e.g., immigrants). Their employees are frequently not informed about the hazards that they dealt with. Just to mention a relevant experience, a pilot research project was carried out in the Latium region in Italy, regarding the training needs for different foreign workers (e.g., from India, Romania) offering classrooms with native tutors. The main purpose was to disseminate useful information allowing for a better comprehension of the intimate relationship among risk perception of farmers and the key risks to which they are exposed (Jacinto et al., 2009).

Exploring job accidents that occurred following not only the location, temporal period but also the local socio-demographic profile of persons involved (e.g., by investigated the impact of age, gender, and nationality) and correlating these episodes with background agricultural and forest data, should provide useful and spatially differentiated information about safety work conditions. Moreover, future scenarios can be proposed resulting from a detailed analysis of inherent risk factors. Operating conditions in divergent working areas aims to establish suitable technical, legislative and operational strategies containing manifold job risks. Without a thorough reflection on the specific job condition, the analysis of the impact of legal contracts and formal obligations on job risk in agriculture can be meaningless.

7.3.1. Accidents at work in Italy

Italy has a long historic background in statistical reporting and analysis of accidents at work when compared to other European countries (Jørgensen, 2008). Thanks to the National Institute of Insurance (INAIL) founded in 1883, compulsory insurance against accidents at work was enforced in 1946, covering all types of employees. The dataset elaborated derived from elementary data concerning accidents that occurred in Italy between 2012 and 2017, focusing on the primary sector, which can be divided into three basic economic activities: (i) cultivations and production of animal products, hunting and related service activities; (ii) fisheries and aquaculture; and (iii) forestry. Such a dataset permits the analysis of the following matters: (i) when an accident occurs; (ii) its main consequence for workers (fatal or not); (iii) age, gender and nationality of the involved worker. Aggregated statistics were managed in an ArcMap environment, GIS (Geographic Information System) software from ESRI, which allowed spatially explicit analysis of relevant indicators. With GIS tools, it was possible to detect where the highest number of events occurred in Italy. The spatial unit of analysis was the administrative province. The scale is chosen because INAIL does not provide more detailed information about the area where the critical event occurred, to assure protection of personal data according to the European statistical regulation on privacy. However, the month and year when the event occurred is provided. Such information is essential for correlating existing agricultural and forest circumstances with potential dangers in a defined area. Further indicators were collected. They are available in the most recent agricultural census (2011) available from the Italian National Statistical Institute (ISTAT) database. Integrated variables allowed a description of basic characteristics of the rural sector (e.g., utilized agricultural area). Consequently, two datasets were correlated using statistical techniques. A Principal Component Analysis (PCA) was run on the indicators' matrix, with the final objective to recognize similarity patterns among Italian provinces, demonstrating spatial trends in work accidents, mainly based along a north-south geographical gradient.

7.3.2. Spatial outcomes from job accidents

Following the study period (2012-2017), the empirical analysis presented has focused on the different characteristics emerging from recorded injuries in the primary sector (Figure 7.5). In Italy, nearly 21,100 accidents at work occurred in the past 6 years, including about 100 fatalities. The amount of injuries (including the fatal ones) has followed a declining trend over time. Such tendency can be influenced by a more effective dissemination of technical information to workers through specific courses/training on

safety at work being compulsory in many cases before signing a job contract. Nevertheless, this decline may have been also affected by the 2007 economic crisis since a lower number of employees is correlated with a lower risk of job accidents. The unluckiest months, with the highest accident rates in Italy, are March (1832 accidents), June (2015), July (2015), September (1934), and October (1890). These statistics also replicate major agricultural practices, including-but not limited to-the collection of rural products.

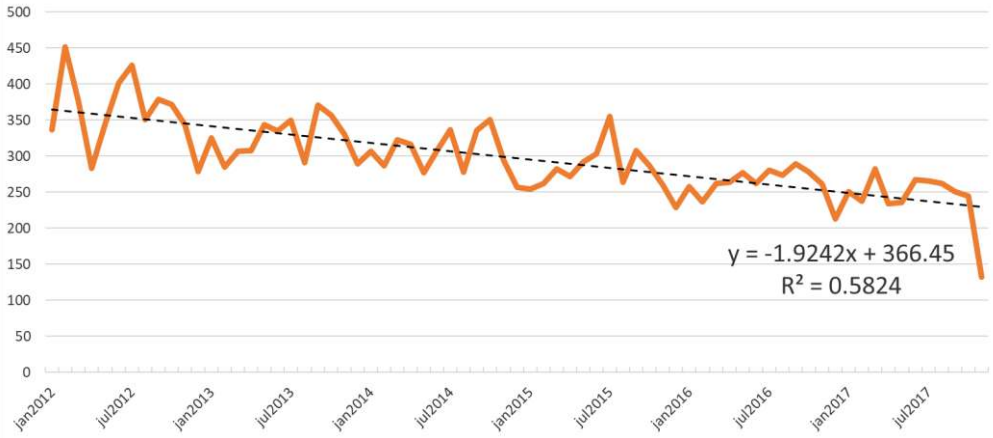
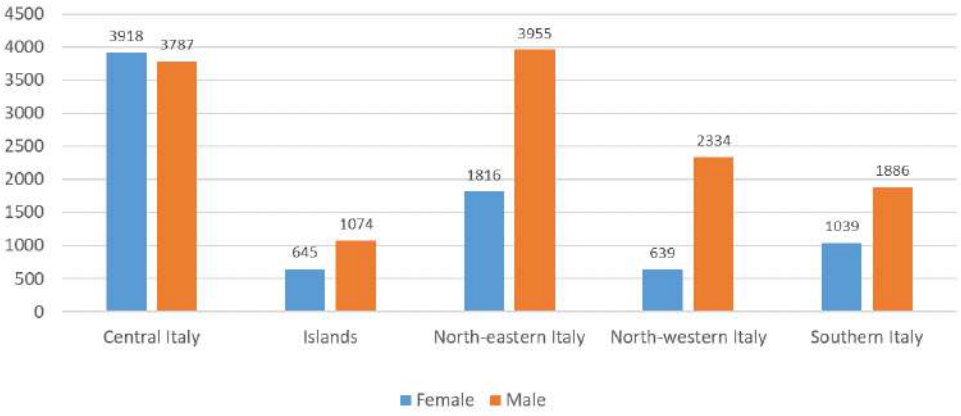
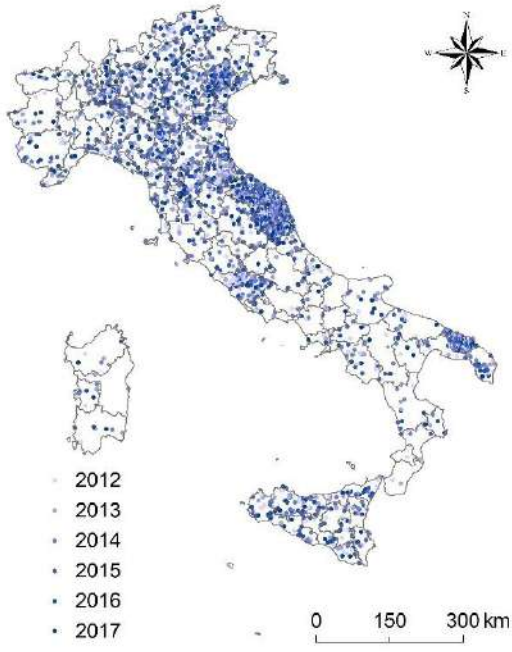


Figure 7.5. Accident trend in the primary sector in Italy over time (2012-2017).

The greatest amount of injuries occurred in central and northern Italy (Figure 7.6). There was a high number of accidents in central Italy, with a specific exposure of the female population (a); however, in the other macro-regions, the highest number of people injured was male. The administrative region with the largest amount of accidents is Marche, totalizing 4825 events overall (b).



(**a**)



(**b**)

Figure 7.6. People (males in blue and females in orange) involved in accidents by geographical subdivision (a) and distribution of accidents occurred in Italy; (b) by year (from 2012 to 2017).

The age groups between 35 and 60 years assumed the highest number of accidents in the past 5 years: there were almost 15,000 injuries with people in this age cluster (about 71% of the sample). Moreover, the average age of the injured people was over 50 years old in Sicily (southern Italy); however, the age range between 45 and 50 years was the most representative class for accidents recorded in central Italy and in the districts along the Po river, as well as in Sardinia.

The proposed examination also acknowledged the foreign population involved in work-related injuries. The Romanian population is the most affected one in the past 6 years: 533 people were involved in accidents at work. In any geographical distribution in Italy, Romanians are continuously the largest number of people injured, followed by Moroccans (309 events), Albanians (261) and Macedonians (121).

A comparison of these data with contextual information derived from the Italian agricultural census may shed more light on the spatio-temporal pattern of job accidents in agriculture. Six indicators were then calculated: (i) number of people employed in agriculture on utilized agricultural area (UAA); (ii) ratio of utilized agricultural area (UAA) on the total agricultural area (TAA); (iii) number of accidents on the number of people employed in agriculture per 1000 employees; (iv) number of accidents in relation to utilized agricultural area (UAA); (v) number of accidents normalized in relation to the utilized agricultural area (UAA) on the total agricultural area (TAA); (vi) percent change of the total number of accidents recorded in 2017 (the final year of investigation) and 2012 (the first year of investigation).

The areas that experience the strongest incidence of workers in the primary sector relative to Utilized Agricultural Area (UAA) are situated along coastal areas, flat lands and the main waterways (e.g., Po River), possibly indicating agricultural intensification. However, the inland mountainous regions have a lower rate for this indicator. Strongly used rural areas are the northern districts, especially along the Po river, some central provinces (e.g., Viterbo), the major islands and the Apulia region. As already mentioned, the highest amount of accidents at work to the total number of people employed in agriculture per 1000 employees was recorded in the north-central areas of Italy (e.g., Aosta, a large part of Veneto, Marche and Trentino); the only southern province which recorded a particularly high rate is Foggia, having a high value of UAA in TAA. The fourth indicator integrated the previous ones, indicating together (i) the most productive agricultural areas; and (ii) the most dangerous territorial contexts, which are associated with a

high incidence of employees. The empirical findings showed also the riskiest provinces (Vicenza, Lucca and Roma) based on the amount of fatalities. The fifth indicator quantifies the number of accidents relative to the utilized agricultural area (UAA) and total agricultural area (TAA). In this instance, the most sensitive areas to job accidents are situated in central Italy, especially Marche region, which totalized the highest share of injuries.

The last indicator assesses percentage variation in the target variable between the final and initial year of investigation. Eleven provinces reported an increase in job-related accidents over time. A few of them are situated in north-western Italy (Cuneo, Aosta, Como, Monza and Brianza), while most of them are distributed in central-southern regions (Benevento, Teramo, Matera, Isernia, Prato, Crotone, Verbano-Cusio-Ossola). Conversely, the provinces that have experienced a halving of work-related injuries are situated in central and northern districts of Italy (e.g., Belluno, Forli'-Cesena, Siena, Rome). A few of them are situated in southern Italy (e.g., Salerno, L'Aquila, Campobasso, Reggio Calabria, Barletta-Andria-Trani). The large majority (90%) of Italian provinces witnessed a decrease over time in accidents at work in the primary sector.

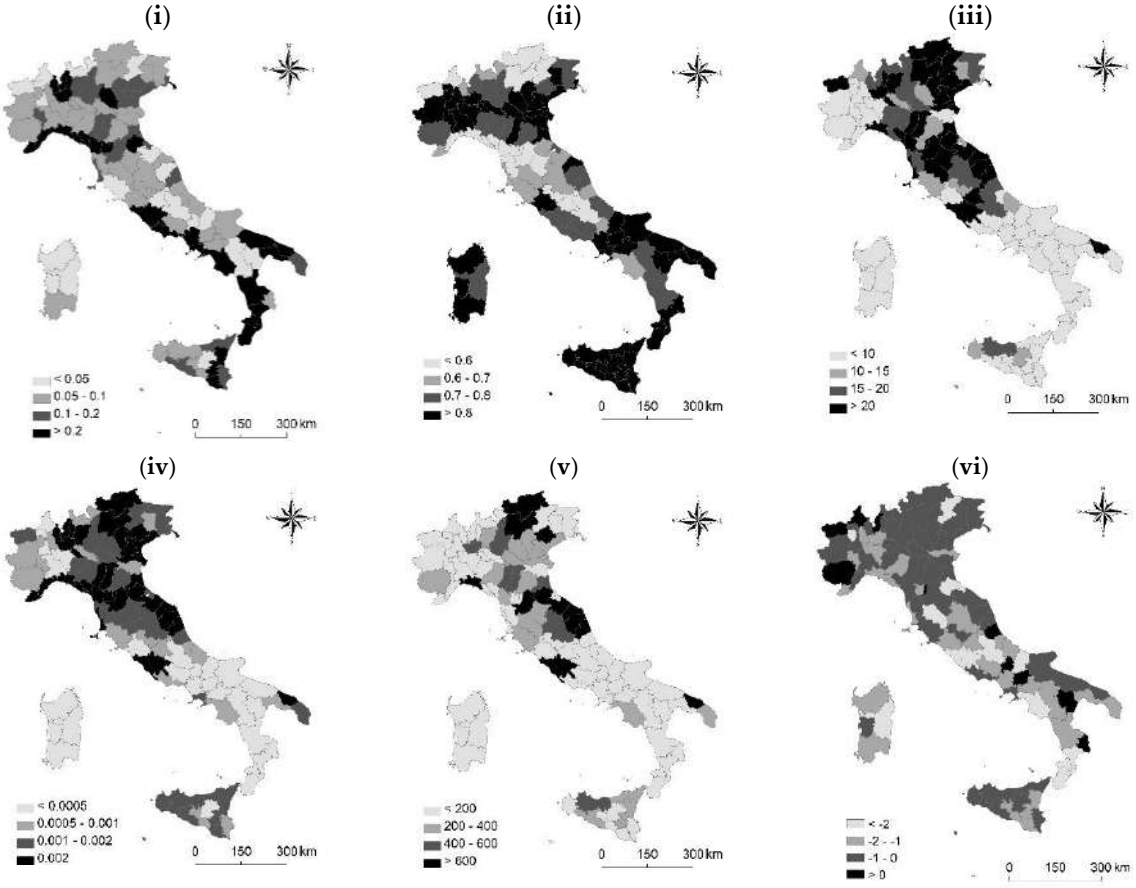


Figure 7.7. Selected indicators illustrating (i) the number of people employed in agriculture on utilized agricultural area (UAA); (ii) the ratio of utilized agricultural area (UAA) in the total agricultural area (TAA); (iii) the number of accidents in the total number of people employed in agriculture (per 1000 employees); (iv) the number of accidents to the total UAA; (v) the number of accidents to the total UAA, normalized by TAA); and, finally, (vi) the per cent variation between accidents occurred in 2017 (final year of investigation) and 2012 (first year of investigation).

To assess whether recent job accidents take on the same trends, PCA results show the overall performance of each Italian province (Figure 7.8). According to components 1 and 2, Marche assumed a specific distribution in respect with the other areas, due to the high number of accidents recorded. Territorial areas that experienced the highest values as for accidents per 1000 employees and per UAA are shown in the right part of the graph. Three provinces (Forlì, Brindisi and Rome) offer a specific outline:

accidents in these areas occur especially during autumn (e.g., October). This outcome is possibly connected to the dominant cropping system, based on vineyards and/or fruit crop. Component 3 highlighted the areas with a strong incidence of accidents in the first year of detection (2012), mainly corresponding to winter months. PC4 outlined the provinces with a particularly high accident rate in 2014, and a lower rate for 2016. The analysis also shows accidents occurred in February, consequently revealing a larger risk of agricultural practices correlated with soil preparation.

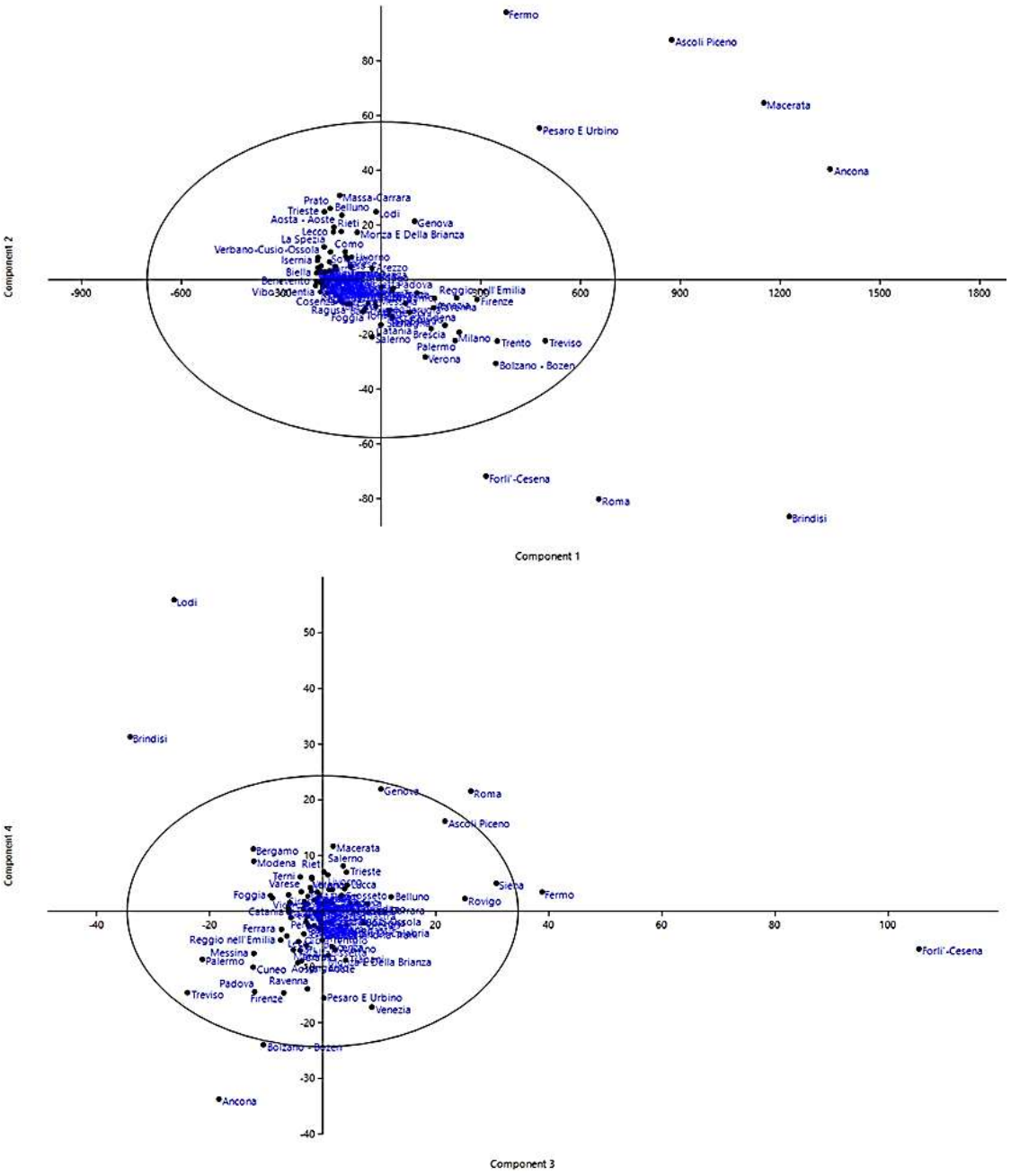


Figure 7.8. Score plot of principal components (upper panel: PC 1 vs. 2; lower panel: PC 3 vs. 4).

7.3.3. Future implications in job safety

The chief objective was to identify the most relevant accident causes, intended as a knowledge base to define appropriate prevention measures (Jørgensen, 2008; Jacinto and Aspinwall, 2004). In these respects, statistics were collected in a comparable form across countries and were updated in suitable datasets following classification systems and official registration measures (Jørgensen, 2008; Dupré, 2000.).

However, standardized legal notification and registration systems are usually not so simple (Jørgensen, 2008), or quite different across European countries (Jacinto and Aspinwall, 2004; Arquillos et al., 2012). The (changing) geography of accidents at work in the primary sector is a quite unexplored topic in the scientific literature (Fabiano et al., 2004). In this regard, major attention is often given to other economic sectors deemed to be hazardous, e.g., construction activities (Fernández-Muñiz et al., 2018; Suárez-Cebador et al., 2014; López et al., 2008; Purschwitz et al., 1986.).

As far as safe working in agriculture is concerned, the existing programs to reduce injuries are often grounded on a largely variable (and sometimes mixed) understanding of related risky activities (Stoneman et al., 2014). Exploring job accidents in selected socio-demographic dimensions (e.g., place, gender, age, nationality of the person involved) bring about the opportunity to examine the intimate characteristics of the working environment. Empirical findings revealed that the number of injuries has followed a declining trend over time, likely influenced by a thorough (often compulsory) supply of educational courses dealing with safety at work. For the primary sector, the most critical months are March, June, July, September and October, which likely reflect the most dangerous agricultural practices. Results proved that the greatest number of injuries occurred in central and northern Italy, with a specific socio-demographic profile (males aged 35-60 years old). The influence of agricultural workplace accidents on older people can expose a requirement to oversee the role that increased age plays in relation to performance and attention in the workplace (Stoneman et al., 2014).

With continuous routine, risks may be more lightly perceived during certain custom practices, while being a potential for accident involvement. Therefore, risk perception is strongly linked to having attended training courses; nevertheless, those workers who attended courses do not always assume a safe performance (L'abbate et al., 2010; Klepacki, 2008). An improved analysis of the tasks to be carried out and the quality of training is essential since information and training-at least in the primary sector-cannot be acquired mechanically but constitute a real dynamic process (Purschwitz and Field, 1990).

Also, the foreign population was involved in work-related injuries, especially Romanian people. The analysis of statistical indicators makes it possible to evaluate exposure to risk of work accidents. However, it is also necessary to integrate this data with information on irregular jobs typical of certain areas. For instance, in southern Italy, work is often irregular and without any legal contract: in the instance of a professional accident, the employee is not protected and cannot report the episode. Moreover, in Italy, as in other countries such as in France, statistics are also used to establish (business) contribution rates to ensure coverage of costs arising from accidents at work (Jørgensen, 1997). Therefore, the social safekeeping rate is variable, depending on accident costs. Such policies can be used to a greater extent as an economic incentive for the introduction of preventive measures (Jacinto and Aspinwall, 2004; Dupré, 2000). Conversely, the financial pressure on employers could lead to an under-declaration of accidents (Jørgensen, 1997).

By giving new job opportunities to the primary sector, which plays a fundamental role for the environment, landscape and food production (Klepacki, 2008; Di Giacinto et al., 2012; Moscetti et al., 2014; Salvati and Carlucci, 2011), working safety protocol is unavoidable. While taking care of workers' safety, farming activities continue to play a great role in regional economic systems (Kosmas et al., 2016; Ferrara et al., 2014; Serra et al., 2014; Wysokiński, 2015; Colantoni et al., 2016). Environments characterizing a farmer's job should be explicitly described and assessed in a comprehensive way (Akdur et al., 2010; Boubaker et al., 2016; Dell'Antonia et al., 2013). Each type of accident should be classified according to standard nomenclature. Unfortunately, such specification is missing (e.g., overturning of tractors, other machinery, chemicals, mobile machinery) from some periods in the databases. Such enlightening lack should be filled with inferential procedures to identify which agricultural practices cause the most accidents and to design more specific training courses. Even if the amount of accidents has decreased over

time, the increase in the sum of educational courses on safety at work is particularly relevant in Italy. A decline in job fatalities may also have been affected by the economic crisis, since a low number of employees is correlates with a low risk of accidents.

Industrial policies and rural development strategies should also propose innovative solutions for the primary sector, since it is essential that operators' safety is guaranteed during the production process. Since the current incidence of injuries in the agricultural sector is still relevant in Italy, careful analysis of the most effective interventions should be addressed and implemented. In this regard, accurate recommendations may combine practical, organizational and training actions (Gil Coury et al., 1999; Lee et al., 2012; Robert et al., 2015). In particular, in risky areas of the country, educational and training models should be implemented, defining a set of priorities, such as: (i) an interdisciplinary program providing more specialized courses, in addition to the plan foreseen by law; (ii) an analysis of training targets and profiles; (iii) a definition of degrees of knowledge and competences of the trainers; (iv) development of technical sectors run by sector experts; and (v) dissemination of the model through info-points promoting awareness to job accidents. Only by adopting a dynamic and contextualized model can a pilot assessment give positive outcomes in a given territorial area. Also, the knowledge and application of precision farming technologies can be useful to prevent potential risks in rural activities (Solomon, 2002; Colantoni et al., 2018). In fact, the fall in accidents is due to several factors which do not involve training. For instance, the decreasing rate may be due to greater automation and technologies in the agricultural sector. In addition, data processing is essential, such as the number of accidents that be normalized based on total hours worked by workers. However, in Italy, databases are not available; in the United States, industries are supervised by OSH (Occupational Safety and Health) and given as TRIR (Total Recordable Incident Rate) in accident units/100,000 h worked. The data analyzed refer to Italy, and empirical findings may differ from those observed in other countries (Fernández-Muñiz et al., 2018), but they may give insights into relevant common variables. Incidents that are not reported are excluded from the analysis. In future research, integrated indicators should be constructed with the aim of obtaining a more accurate approach to their influence on work accidents. For instance, climate variables may designate whether there are variances in the severity of accidents across Mediterranean areas and/or continental regions. Different training strategies need to be improved by advancing effectiveness of the agricultural workers' training.

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8. Identifying, planning and designing agro-energy districts

The current energy guidelines requested by the European Community encourage the use of renewable resources as a potential alternative supply to traditional fossil fuels (Abazaj et al., 2016; Colantoni et al., 2016a, b; Galik and Abt, 2016; Giacomarra and Bono, 2015). By supporting sustainable development, energy needs can be met through the conversion of agroforestry biomass into biofuels (Daioglou et al., 2016; Giwa et al., 2017; Martire et al., 2015a; Sharma et al., 2016; Zambon et al., 2017a, 2018). Therefore, a requirement for establishing sustainable production and consumption chains at the local level emerges (Zambon et al., 2016a, b; Martire et al., 2015b). Accurate planning becomes crucial to ensure the planning and establishment of agro-energy districts (Colantoni et al., 2016a; Albino et al., 2007; Biasi et al., 2015; Manos et al., 2014). Such a procedure requires a careful analysis of potential energy capitals that can be obtained in each territorial area (Zambon et al., 2017a, b). It should be reminisced that the primary sector in Europe (and more specifically in Italy) has suffered a severe decline in recent decades, e.g., the loss of employment and an increase of abandoned rural areas (Zambon et al., 2017a; Agnoletti et al., 2007; Navarro and Pereira, 2012; Salvati and Zitti, 2007). By re-establishing rural landscapes and promoting multifunctional agriculture, agroenergy districts arise as competitive and sustainable certainties for agricultural contexts (Colantoni et al., 2016a, b; Zambon et al., 2017b, c, d; Macrì et al., 2016).

8.1. Identification of an agro-energy district

The rural landscapes of Mediterranean Europe are characterized by their peculiar crops, whose agricultural practices have led to different land use changes (Bonet, 2004). In recent years, there has been a strong abandonment of agricultural areas (Godone et al., 2014; Sitzia et al., 2010), supporting a consequent reforestation development (Bonet, 2004; Sluiter and de Jong, 2007).

Sustainability is often explained through three dimensions: society, economy and environment (Bonet, 2004; Sluiter and de Jong, 2007; Godone et al., 2014; Sitzia et al., 2010). However, such definition currently appears to be restricted (FAO, 2010; Aydinoglu, 2010; Reis and Yomralioglu, 2006). Sustainable development often includes the energy dimension, e.g. to guarantee a suitable energy efficiency (TURKSTAT, 2001; Sarıoğlu et al., 2013; Martinez-Casasnovas et al., 2010). Though energetic sustainability considers both energies required to achieve a task and that can be sustained by the power supplied from the environment (Van Berkel and Verburg, 2011; Westhoek et al., 2006). In literature, several contributions looked out for explaining why sustainability does not include the energy dimension, stressing on economic processes that do not take energy into consideration (Official Gazette, 2009; Dengiz et al., 2010). In this sense new theories were born. For instance, bio-economy assumes a meaning in recent years that binds energy and economy, strengthening and comprehending environmental and sustainability issues (Dengiz et al., 2010).

Cited article

Zambon, I., Delfanti, L., Marucci, A., Bedini, R., Bessone, W., Cecchini, M., Monarca, D. (2017). Identification Of Optimal Mechanization Processes For Harvesting Hazelnuts Based On Geospatial Technologies In Sicily (Southern Italy). Agriculture 7, 56.

In this framework, bio-economy assumes a decisive role in the development of local rural realities (Longley et al., 2001), combining economic growth and respect for the environment (Bolca et al., 2011). In countryside areas, the energy component can be merged with the sustainable development (Martinez-Casasnovas et al., 2010; Van Berkel and Verburg, 2011; Westhoek et al., 2006) by creating agro-energetic districts (Wilkinson, 2005). The global energy state is generally characterized by agricultural residues, a dependence on firewood, animal power and manure to cover primarily subsistence energy needs. Therefore, rural areas can offer a large energy contribution in the form of biomass (Reis and Taşdemir, 2011). Biomass constitutes the main global energy source for almost 50% (Yomralioglu et al., 2009); for instance, wood biomass is a current key renewable energy source, on behalf of a relevant amount of rural

energy supply (Cohen and Shoshany, 2002).

As a solution for socioeconomic, environmental and political issues (Grauke and Thompson, 2003), bioenergy is based on the sustainable use of renewable resources (e.g. solar plants) and biomass (e.g. agricultural wastes), taking up a real choice for the supply of energy services (Yomralioglu et al., 2009). For instance, various benefits derive from it, ranging from the simple energy provision to opportunities for regional growth (Mundia and Aniya, 2005).

Working as a network of local agricultural firms, agro-energy districts can be an example of realities founded on bioenergy (Wilkinson, 2005). Achieving energy self-sufficiency, such local network attempts to guarantee simultaneously zero impact energy compared to fossil fuels, rural development, food security, local self-sufficiency, sustainable agricultural management, biodiversity, conservation and climate change mitigation (Yuan et al., 2005). Through agro-energy chains can provide innovative local solutions, both in terms of advanced technology, management and economy in the primary sector using local and regional biomass supply (Wilkinson, 2005; Franco, 1997; Kavzoglu, 2009; De Aranzabal et al., 2008).

Even if agro-energy districts are defined as highly sustainable systems, some research activities also addressed that an increasing expansion of these realities can cause over-exploitation of soil fertility, undesirable changes and conflicts among different land-use choices (Wilkinson, 2005; Franco, 1997; Kavzoglu, 2009; De Aranzabal et al., 2008). This assumption derives from often speculative actions cause unsuitable manipulation. For instance, in the last decades, solar plants have had a strong expansion in Italy. While they offer energy from renewable sources, a large amount of agricultural land has been occupied by solar plants, turning out negative processes of soil degradation (Yalniz and Aksoy 2009).

The identification of energy districts in rural areas highlights the lack of appropriate tools for decision making and planning at the different scales. Planners must apply an interdisciplinary approach to select the most appropriate method of analysis. Identifying and applying an effective planning methodology to be applied throughout the European community is essential (Kimes et al., 1998).

8.1.1. The role of sustainability and energy for local economies

Stressing on an innovative economic growth of rural contexts, arose from the need to take environmental measures (Biondi et al., 2007), the concept of sustainability has taken on a broader meaning (Gianguzzi et al., 2016). Sustainable development policies and strategies must achieve a reliable equilibrium between economy and ecosystem protection, (i) reconciling production and environmental requirements and (ii) ensuring competitiveness and local attractiveness (Pedrotti, 2004). Nevertheless, quantitative methods to support local sustainability are lacking (Rivas-Martínez, 2005) since the complexity of the notion of sustainability makes difficult to predict which policy can better integrate human needs, economic growth and environmental quality (Duran, 2015). In this framework, emerging renewable energies (such as biomass) have become an essential element for encouraging and supporting the development of rural areas (Ozturk et al., 2007). Taking operative actions and restricting negative effects on the local environment, several studies proposed modelling techniques for economic, energy and environmental analysis concerning agro-energy supply chains and their locations (Tanik et al., 2016). The sustainability existing in agro-energy supply chains involves not only (i) energy and the use of renewable energies, but also embraces (ii) environmental issues, by improving the socio-economic sphere such as (iii) the level of different farmers and (iv) the local income (Gianguzzi et al., 2015; Tanik et al., 2016; Monarca et al., 2005; Formato et al., 2013; Recanatesi et al., 2013).

8.1.2. Potential agro-energy districts based on hazelnut production

Hazelnuts represent ones of most produced nut crops in the Mediterranean contexts, as in Italy (FAO,

2010), since as agricultural products have relevant nutritional and economic value (Aydinoglu,). Given their profitability, they are also grown on unsuitable ground, due to the absence of land use policies (as in Langhe region in Italy) (Godone et al., 2014; Reis and Yomralioglu, 2006). For example, Turkey imposed specific regulations for cultivating hazelnuts in given areas, where the maximum elevation is 750 m, the slope is more than 6% and IV or upper class of LCC (TURKSTAT, 2001). According to such government regulations, potential hazelnut areas can be mapped with specific criteria (e.g., slope, elevation, and land use–land cover) using GIS technology (Sarıoğlu et al., 2013). Consequently, their detection may be useful to observe landscape changes, providing greater support to national and international institutions in the assessment of rural agriculture policies (Martinez-Casasnovas et al., 2010) and their latent consequences on local society, landscape, and production (Van Berkel and Verburg, 2011; Westhoek, et al., 2006).

Defining hazelnut areas is possible through maps and satellite images by advanced computer programs such as Geographical Information Systems (GIS) and Remote Sensing (RS) technologies, which offer benefits in data management and acquisition (Aydinoglu, 2010; Official Gazette, 2009). In recent decades, GIS and RS have been appreciated within rural applications linked to resources at several spatial scales (Sarıoğlu et al., 2013; Dengiz et al., 2010). GIS presents a suitable tool for processing, analyzing, and collecting spatial information (Reis and Yomralioglu, 2006; Lioubimtseva and Defourny, 1999; Longley et al., 2001). Spatial analysis reveals elevation, aspect, slope, and soil data using GIS methods and even investigates environmental situations, soil attributes, and topographic changes (Aydinoglu, 2010; Sarıoğlu et al., 2013; Bolca et al., 2011). From RS technologies, land cover classification is regularly achieved by a multi-class scenery and supervised arrangement of textural or spectral characteristics at pixel level (Wilkinson, 2005; Reis and Taşdemir, 2011). Remote sensing imagery permits to provide data about hazelnuts from satellite images (Lillesand and Kiefer, 2000), which can be then integrated to other database in GIS with the aim of securing sustainable development of rural areas (Aydinoglu, 2010; Cohen and Shoshany, 2002; Grauke et al., 2003; Yomralioglu et al., 2009). Therefore, through Geographical Information Systems (GIS) and remote sensing with multi-temporal high-resolution satellite data, land use changes, vegetation cover, soil degradation, and further issues can be monitored integrally (Mundia and Aniya, 2005; Yuan et al., 2005).

Remote identification of hazelnuts is not reasonably straightforward (Franco, 1997; Kavzoglu, 2009). However, it is necessary (i) to optimize harvesting methods and (ii) to distinguish rural landscape dynamics and socio-economic and land use changes to achieve sustainable development (De Aranzabal et al., 2008; Tzanopoulos et al., 2012). Their detection usually takes place through a visual interpretation of very high-resolution remote sensing imagery to exploit spectral and textural features, due to the absence of an automated method (Reis and Taşdemir, 2011). However, few studies have focused on mapping hazel groves with high resolution imagery (Reis and Yomralioglu, 2006; Reis and Taşdemir, 2011; Fabi and Varvaro, 2009; Taşdemir, 2012; Yalniz and Aksoy, 2009). Vegetation variables appear continuous and difficult to distinguish, e.g., biomass, fraction of vegetation cover, or leaf area index (Kavzoglu, 2009; Kimes et al., 1998). For instance, NDVI values appear very close for hazel groves and further woody vegetation (Reis and Taşdemir, 2011). In fact, it is difficult distinguishing hazelnuts from forest areas and other similar crops (such as olives) that are also typical of the Mediterranean landscape (Aslan and Özdemir, 2004). Their identification from other areas can decrease the inventory expenses by saving money and time (Aslan and Özdemir, 2004). The existence of vegetation maps, performed through Geographic Information Systems (GIS), can be useful for both qualitative and quantitative assessments of natural resources in a definite context (Biondi et al., 1998, 2007; Gianguzzi et al., 2016; Pedrotti, 2004; Rivas-Martínez, 2005).

The importance of having analytical parameters is essential to find hazelnut plants. The latter are usually located at an altitude of 500 and 1000 m (Duran, 2015). Their typical altimetry is motivated by the degree of humidity and climate, with a slope between 6% and 30% (Aydinoglu, 2010). Furthermore, the

cultivation of hazelnuts is not recommended on steep slopes, since they are not able to prevent and hinder potential soil erosion processes (Ozturk et al., 2007; Tanik et al., 2008).

Hazelnut production is frequently characterized by irregular plantations and inconstant density, from steep slopes and rough terrain environments (Monarca et al., 2016). There are several mechanization methods for collecting hazelnuts, aiming to rationalize costs and harvest production using appropriate existing technologies (Monarca et al., 2008; Formato et al 2013). Several research activities have been launched to assess the collection of hazelnuts, minimizing the risks for the operators in the field (e.g., risk of overturning) (Monarca et al., 2016). Hazelnuts are usually planted in rows along which herbicides are distributed during the year on the herbaceous vegetation for improving mechanical operation during the harvest (Recanatesi et al., 2013). The major problem during the hazelnut collection concerns the situations of high slopes and terraces in addition to the risk of roll-over problems (Monarca et al., 2016). Furthermore, the intense hazelnut harvesting can lead to negative consequences (e.g., soil erosion) (Recanatesi et al., 2013) and it is therefore necessary to evaluate how to optimize the collection depending on the soil characteristics.

The purpose was to identify hazelnuts with the aim of proposing strategies and optimizing mechanization systems through geo-spatial technologies. The case study focuses on 10 municipalities in the Sicily region, which are part of the National association of hazelnuts. In these contexts, many hazelnut plantations appear to be woods. Hazelnuts have well-adapted in the Nebrodi mountains (Gianguzzi et al., 2016), but very often are in problematic areas to reach and work in safety. The cultivation of hazelnuts in Sicily covers a surface area of 16,482 hectares, producing each year around 204,306 quintals. The diffusion of hazelnut trees in this context took place in 1890, after the crisis of gelsiculture. Today, thanks to their ease of adaptation, dense root system and profitable productivity, hazelnuts are the predominant yield of the Nebrodi agrarian landscape (Gianguzzi et al., 2016). In this regard, the municipalities of the province of Messina of Castell'Umberto, Montalbano Elicona, Sant'Angelo di Brolo, Raccuja, Santa Domenica Vittoria, San Piero Patti, San Salvatore Fitalia, Sinagra, Tortorici and Ucria are part of the National Association of Hazel Towns ('Associazione Nazionale Città della Nocciola'), representing the region of Sicily.

Recognizing the most suitable areas can contribute to the primary sector in economic terms, estimating the potential hazelnut cultivation, ensuring opportunities for cultivation and the security for operators during the harvesting according to the intrinsic characteristics of such context. In this framework, an optimization of collection and mechanization processes, depending on geo-morphological and territorial characteristics and avoiding possible pollution, was reached. This first examination estimates the biomass obtained from suitable hazelnut plants pruning, as a real solution to produce energy through thermo-chemical processes, i.e., combustion, gasification, and pyrolysis (Bilandzija et al., 2012). Finally, the consolidation of an agro-energetic district was suggested in this context. The latter provides several benefits, as it strengthens the local economy linked to the cultivation of hazelnuts and can start a reality based on the circular economy with the purpose of re-using agricultural residues for energy purposes.

8.1.3. Definition of an analysis process

ESRI ArcGIS software was used to integrate data and accomplish spatial analysis (Aydinoglu, 2010). GIS technology is decisive to spatial surveys for examining the context of the study. As computer-based system, it allows to capture, storage, recovery, analyze and display geographic data (Longley et al., 2001). GIS techniques were used to overlay maps (vegetation map of Sicily, Corine Land Cover (CLC), and other geospatial data, as well as road system), to make elaborations examining where the hazelnuts are located and to hypothesize mechanization processes focusing on some of their morphological characteristics: DTM, slope, aspect and curvature. The National Terrain Model (DTM) map is the representation of the interpolation of orographic data from the map of the Military Geographic Institute. The resulting product is a 20 m regular step matrix, whose elements (pixels) show the values of the quotas. The Slope identifies

the maximum rate of change in value from that cell to its neighbors. Principally, the maximum change in elevation over the distance (among the cell and its eight neighbors) finds the steepest downhill descent from the cell. The Curvature displays the shape or curvature of the slope and is calculated by computing the second derivative of the surface. The curvature, parallel to the slope, indicates the direction of maximum slope. A part of a surface can be concave or convex, by looking at the curvature value. It affects the acceleration and deceleration of flow across the surface: (i) a negative value indicates that the surface is upwardly convex at that cell, and flow will be decelerated, (ii) a positive profile indicates that the surface is upwardly concave at that cell, and the flow will be accelerated, and (iii) a value of zero indicates that the surface is linear. As the slope direction, aspect displays the downslope direction of the maximum rate of change in value from each cell to its neighbors. The values of each cell in the output raster designate the compass direction that the surface faces at such location, measured in degrees from 0 (north) to 360 (again north). Having no downslope direction, flat areas assume a value of −1.

The vegetation map was used as the base for the land use. It represents a convenient combination of the vegetal landscape, whose complex diversity reproduces the greatest physiographic, geomorphological, lithological, and bioclimatic variability of this region. In fact, the vegetation map is characterized by 36 phytocoenotic categories. As a result of years of research, it gives a summary of the widespread phytosociological and cartographic literature in Sicily. It was performed through Geographic Information Systems (GIS) at several scales (1:50,000, 1:25,000, and 1:10,000) and provides both qualitative and quantitative assessments of natural resources (Biondi et al., 1998, 2007; Gianguzzi et al., 2016; Pedrotti, 2004; Rivas-Martínez, 2005).

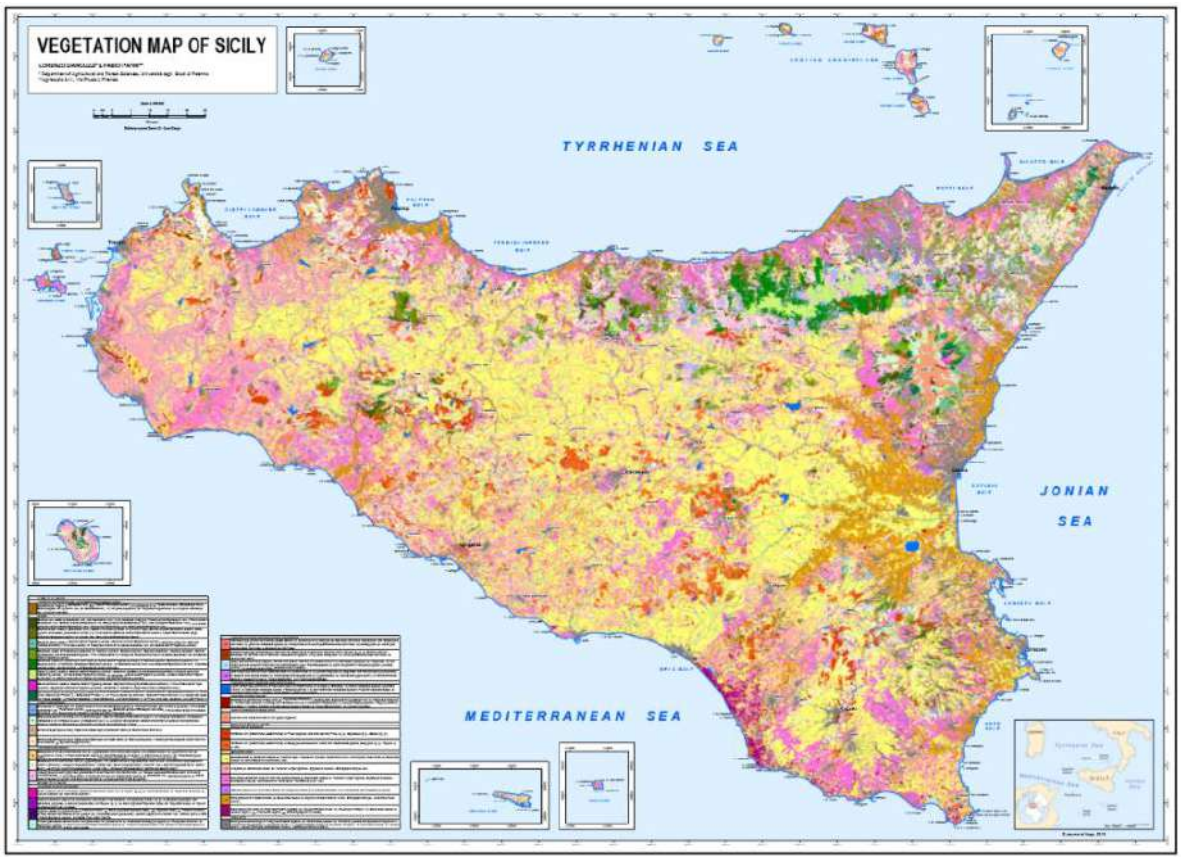


Figure 8.1. A general extaction from the vegetation map of Sicily.

The vegetation map of Sicily was prepared at a 1:250,000 scale according several stages: (i) preparation of a GIS project (1:10,000 scale) with an inclusive database and thematic layers with georeferenced materials, (ii) photo-interpretation of the vegetation with satellite images (e.g., Landsat TM), orthophotos

and digital data on the Technical Map of Sicily; (iii) validations with other maps, such as land use, vegetation or geology, (iv) validation of the photo-interpretation through field survey and verification, (v) digitization of the outcomes and further data, and (vi) phytosociological classification of the mapped types, categorized by 36 phytocoenotic classes (Gianguzzi et al., 2016). Therefore, the vegetation map identifies all the existing crops in Sicily in a precise and detailed way. For instance, hazelnuts (identified with the code 202) occupy a surface area of about 9500 hectares.

8.1.4. Mechanization framework

The cultivation of hazelnuts is characterized by several factors that make it difficult and dangerous to use mechanization systems for operators, at all stages of cultivation, especially in the harvesting phase. Some of these factors are predominantly irregular plantations, a high degree of acclimatization of the slopes (which also reach 35 degrees), uneven ground conditions, a lack or absence of business and interpersonal viability, presence of obstacles to the passage of machines, and unusual soil management with the abandonment of pruning residues on the ground.

The north-eastern part of Sicily along the Nebrodi mountains has seen the spontaneous diffusion of hazelnuts, which have easily adapted (Gianguzzi et al., 2016). Despite their potential productivity, hazelnut plants are placed in very problematic environments, especially for the harvest phase, and therefore most of them are abandoned. Traditional vehicles have difficulty reaching these contexts (e.g., steep slopes that make it unsafe for operator intervention). Therefore, the currently-mechanization methodologies are equal to zero. In fact, harvesting is still by hand-picking in the few cultivated areas.

The prototype tested by (Monarca et al., 2016) can be suggested, using a similar device that is self-propelled and easily transportable for harvesting in areas with poor or absent roads between farms (Figure 8.2). The device can move even under critical slope circumstances (even up to 30–35%) and overcoming substantial difficulties (e.g., terraces, where can be assemble the harvester to a mini crawler with hydraulic or hydrostatic transmission). In this manner, mechanization can be introduced in principally disadvantaged areas, with consequences in terms of safety for operators and a cost-benefit decrease. In operational stages, however, their prototype collects in a stationary position with the assistance of a suction line, permitting operation on highly sloped surfaces (more than 20%). The prototype tested by (Monarca et al., 2016) is ideal for this Sicilian context, avoiding problems linked to steep slopes and movement among hazelnut groves.

Figure 8.2. Photo of the small-scale machine for nuts harvesting proposed (Monarca et al., 2016).

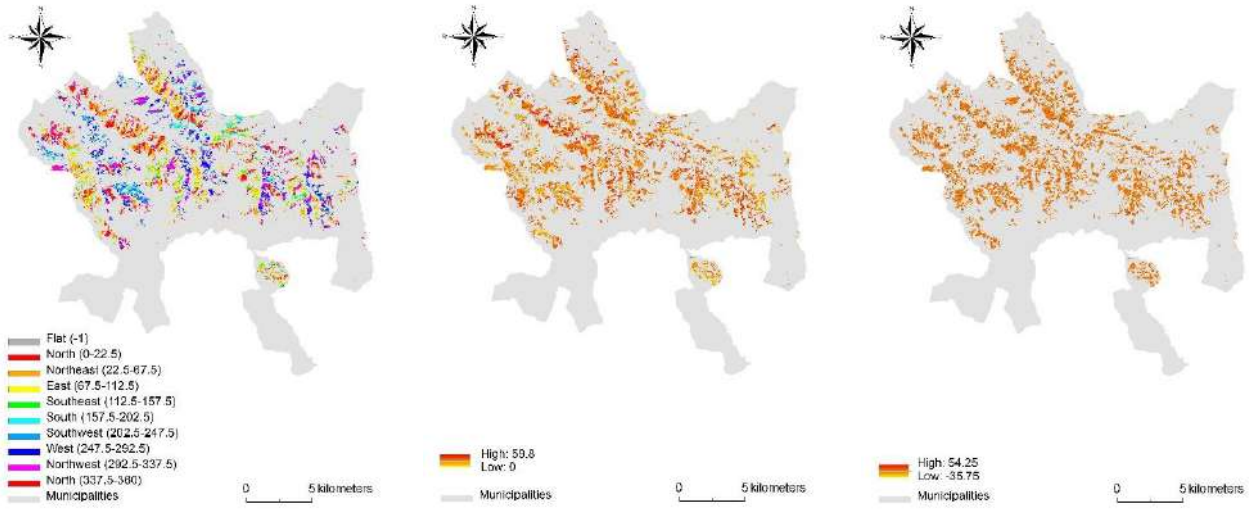
8.1.5. Spatial detection

By means of a first GIS processing, the municipalities chosen are counted on a surface area of almost 4970 hectares (representing 52% of the hazels in the Sicily region). Comparing the vegetation map with the

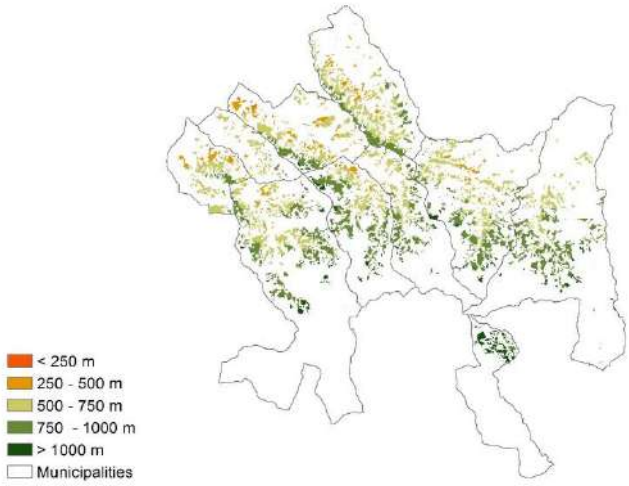
CLC, the accuracy of the first map was confirmed. While the CLC considered hazelnuts as forests, the vegetation map of the Sicily region highlighted their presence as hazelnuts (code 202). By comparing the two maps, 63% of the hazelnuts identified as "orchards" in CLC, while 22% are categorized as "deciduous forests" in CLC. As a first clarification, the CLC tends to aggregate hazelnuts in the category "orchards". Nonetheless, many fields of hazelnuts (22%) visually appeared as forests.

Representing 43% of the hazelnuts considered, San Piero Patti and Tortorici are the municipalities that recorded the highest presence of hazel trees within their administrative boundaries. Hazelnuts plants prefer high altitudes. In fact, 84% of them can be observed between 500 and 1000 m above sea level (with an average of 755 m by examining municipalities in analysis). Castell'Umberto, San Salvatore di Fitalia, Sant'Angelo di Brolo, and Sinagra are the municipalities that identified a larger percentage of hazelnuts at a moderate altimeter than the others, i.e., between 500 and 750 m. The municipality of Santa Domenica Vittoria demonstrated that 86% of its hazelnuts are above 1000 m, although it recorded, in quantitative terms, a reduced surface area for hazelnuts compared to other study contexts.

Through the GIS program, maps concerning DTM, slope (classified in percentage terms), aspect, and curvature were produced (Figure 8.3). Starting from a DTM map the slope of the roads, which must be driven by the vehicles, and the specific slope of each hazelnut areas were calculated. Ambiguous contexts (such as a high degree of slope or altitude) have been assessed in a parallel analysis through available orthophoto investigation, even if the vegetation map detected hazelnut plants. Within this operation, the elevate degree of correctness of the vegetation map of Sicily can be confirmed.



Aspect Slope Curvature



DTM (in meters)

Figure 8.3. Morphological structures of the territory using GIS program. Source: own elaboration.

The slope of hazelnut areas was classified into seven classes: '1': 0%; '2': 1–10%; '3': 11–20%; '4': 21–30%; '5': 31–40%; '6': 41–50%; '7': >50%. The slope of the streets in the ten municipalities was classified into 17 classes: '1': 0%; '2': 1–2%; '3': 3–4%; '4': 5–6%; '5': 7–8%; '6': 9–10%; '7': 11–12%; '8': 13–14%; '9': 15–16%; '10': 17–18%; '11': 19–20%; '12': 21–22%; '13': 23–24%; '14': 25–26%; '15': 27–28%; '16': 29–30%; '17': >30%. Zones with a steep slope (>30%) and high altitude (>1000 m) are the ones to avoid for mechanized harvesting as it results in increased risk for operators when they should collect hazelnuts.

Through the raster calculator tool using GIS program, the territory was analyzed observing the most suitable places to introduce mechanization processes. The optimal contexts for hazelnuts with minimal risk for operators is where the slope is minimal, with optimum altitudes to hazelnuts and ease in terms of mobility for the machines that need to reach such areas. There are also further favorable contexts for hazelnuts with good altitude and slopes. Finally, areas that should be avoided for greater risk for operators, due to their high altitude and slopes, discontinuous road system with strong slopes.

Checking the results obtained, a region group elaboration was run using the GIS program. It identifies the degree of feasibility of cultivation and collection of hazelnuts depending on the morphological characteristics. Four groups of hazelnut areas can be observed. In this elaboration, the most optimal contexts emerge both to grow and manage the cultivation of hazelnuts and to provide the right security measures for the operators who must collect the hazelnuts (class "1"). In fact, in Figure 8.4, it is possible to clearly distinguish the southern zones, which are the ones that are higher in altitude (>1000 m), sloping (>30%) and mostly affect the safety of workers (class "4"). However, the best areas ("1") occupy only 430 hectares (about 9% compared to the total surface area of hazelnuts in the ten municipalities). Unsuitable contexts have a surface of 370 hectares (about 7% of the total surface area in analysis). The intermediate areas (classes "2" and "3" for the region group elaboration) are those that occupy the largest surface areas (almost 4200 hectares). Finally, 4600 hectares can be used as agro-energetic districts.

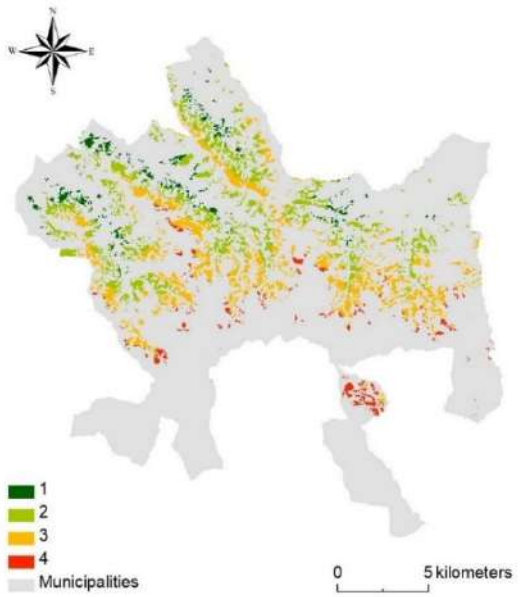


Figure 8.4. Region group elaboration using GIS program to identify the degree of feasibility of cultivation and collection of hazelnuts depending on the morphological and spatial characteristics. Source: own elaboration.

8.1.6. Parameters for long-term permanence of an agro-energy district

Hazelnuts represents one of the major economic realities that constitute the primary sector of the Sicily region (Cotugno, 2011.). The latter is a unique Mediterranean context, given its climate, landscape, and peculiar characteristics (Barbera and Cullotta, 2012; Colantoni et al., 2015a, b). Particularly, the Nebroidi park allows for the easy adaptability of hazelnuts (Gianguzzi et al., 2016). However, high altitudes and the acclivity of slopes make it difficult to cultivate and harvest hazelnuts (Ozturk et al., 2007; Tanik et al., 2008). Identifying the most favorable contexts can increase the growing and harvesting of hazelnuts using appropriate vehicles. First, the territorial characteristics should be considered, such as slope or the road system necessary to reach these contexts. Using and processing data through GIS technologies and databases obtained by remote sensing processes at local level was decisive.

Spatial data collection permitted the comparison of different databases. The vegetation map of Sicily has highlighted how a deep knowledge of the local contexts and the use of remote sensing and GIS technologies, in addition to a large bibliographic collection, allows for a detailed analysis, identifying several kinds of crops. In fact, limiting to a CLC map could causes an actual error in calculating surface areas destined for hazelnuts: only 63% of hazelnuts fall into the category of "orchards" in the CLC map. Data processing has confirmed the adequacy of the vegetation map of Sicily: most of the hazelnuts are found at slopes that are not too high (between 6% and 30%) (Aydinoglu, 2010) and at altitudes between 500 and 1000 m (Duran, 2015). GIS processing has thus let to recognize the most appropriate areas for the hazelnuts, since their cultivation is not recommended on the steep slopes, since they cannot prevent and hinder environmental matters, as soil erosion processes (Ozturk et al., 2007; Tanik et al., 2008). Furthermore, when some contexts appeared uncertain (e.g., when the Vegetation map of Sicily detected hazelnut plantations along high degree of slope or altitude), a parallel analysis (orthophoto investigation of specific areas) assessed such outcomes, confirming the high correctness of the Vegetation map of Sicily.

Another issue concerns the collection of hazelnuts. In these contexts, traditional methods are still used, such as hand-picking. This makes the collection of hazelnuts expensive, wasteful, with high labor costs and long working hours. As a possible solution to the mechanization of harvesting the nuts in soils with planting distances and irregular with steep slopes (from 24 to 35%), the prototype, proposed by (Monarca et al., 2016) can adapt to the most difficult conditions. It is not necessary to use other harvester machines.

Very often, hazelnuts are located along inclined slopes or unconnected areas, where traditional means of mechanization fail to work optimally. The prototype (i) is smaller than existing machines, (ii) ensures agility in maneuvering and high stability in steep slopes, (iii) is easy to use and versatile, (iv) reduces capital amortization times, (v) is easy to be transported by simple means such as small trolleys or pickups, (vi) increases the capacity to collect hazelnuts, and (vii) improves working conditions (e.g., substantial reduction in the risk of biomechanical overload compared to manual harvesting). The prototype of (Monarca et al., 2016) allows for simple collection, safeguarding the health and safety of workers, and reduces the time necessary for the hazelnut harvest (e.g., it separates hazelnuts from other elements such as weeds or leaves). Furthermore, as a work accessory, the prototype proposed by (Monarca et al., 2016) fits to other machines depending on the working context.

Besides identifying the most suitable areas, a chance of sustainable development was offered, such as increasing cultivation of hazelnuts, protecting the workers' safety and optimizing work times concerning picking hazelnuts given the intrinsic territorial adversity. The concepts of circular economy and agro-energy districts could be effectively applied in these territories (Colantoni et al., 2016a, b). From the point of view of agro-energetic districts, it is assumed that the former depends on several parameters, i.e., the cultivation type and site and the planting distance, defining the most appropriate use of residual biomass (Bilandzija et al., 2012). For intensive farming of hazelnut, the pruned biomass can reach about 1848 kg/ha (Cecchini et al., 2016). Obtainable residual biomass from hazelnut trees pruning can be positively considered as an actual economic chance for this area. Finally, it is possible to estimate to get a biomass of 8500 kg (4600 hectares). In conclusion, from the economic point of view, a greater cultivation of hazelnuts would also give more employment alternatives, increasing the employment status and leading to a valorization of local agriculture (Cerutti et al., 2016). As in other region (e.g., Latium and Piedmont in Italy or in Turkey) where hazelnuts are important for the primary sector (Reis and Yomralioglu, 2006; TURKSTAT, 2001; Sarıoğlu et al., 2013; Gönenc et al., 2006; Petriccione et al., 2010; Di Giacinto et al., 2014), they can be defined as an economic resource in Sicily since they could provide income opportunities in hilly and mountainous areas where other agricultural activities are limited by the hostile environment (Cerutti et al., 2016). Potential revenue deriving from this kind of cultivation can be estimated depending on how many hectares are put back into culture (Cerutti et al., 2016). Finally, hazelnuts are defined as one of the most profitable fruit, demonstrating a high degree of sustainability, mostly owing to the low input necessities for orchard management and the opportunity of using agricultural waste as potential biomass (Bilandzija et al., 2012; Colantoni et al., 2016a, b; Cecchini et al., 2013; Cerutti et al., 2013; Di Giacinto et al., 2014; Zambon et al., 2016a).

8.2. Innovative agro-forestry supply chain for residual biomass

Biochar is a carbon-rich material produced by thermal decomposition of biomass under oxygen-limited conditions (Lehmann and Stephen, 2009) According to the International Biochar Initiative (IBI), biochar is primarily used for soil applications for both agricultural and environmental gains (Sohi et al., 2009; Manyà, 2012) The IBI definition differentiates biochar from charcoal, whose use is as a fuel for heat, as an absorbent material, or as a reducing agent in metallurgical processes (Lehmann and Stephen, 2009; Manyà, 2012). Thermo-chemical processes include (i) slow pyrolysis (conventional carbonization); (ii) fast pyrolysis; (iii) flash carbonization; and (iv) gasification (Anupam et al., 2016; Jahirul et al., 2012; Hoogwijk et al., 2003; Panwar et al., 2012). During the last two decades, pyrolysis process received more attention from the scientific community, since it is an efficient method for converting biomass into bio-fuel (Jahirul et al., 2012; Demirbas, 2002). The pyrolysis process and its parameters, such as final temperature, pressure, heating rate, and residence time, greatly influence biochar quality (Jahirul et al., 2012). The advantage of slow pyrolysis is to retain up to 50% of the carbon (C) feedstock in stable biochar (Gaunt and Lehmann, J. 2008), which makes it suitable as soil fertilizer. High-temperature pyrolysis (>550 °C) produces biochar with high aromatic content and, therefore, recalcitrant to decomposition (Singh and Cowie, 2008). Biochars produced through low-temperature processes (<550 °C) typically have a less-condensed C structure and are expected to give a better contribution to soil fertility (Steinbeiss et al., 2009). The nature of the biomass feedstock also influences the properties of the produced biochar (Di Blasi et al., 2013; Manyà, 2012). The relation between biochar properties and its potential to improve agricultural soils is a nascent focus area and the appropriate pyrolysis conditions are still unclear (Brewer et al., 2009). Numerous recent studies focused on methodologies for the chemical characterization of biochars (Brewer et al., 2009; Sánchez et al., 2009; Keiluweit et al., 2010), other studies investigated the intrinsic potential of biochar as a soil amendment (Agegnehu et al., 2015; Beesleya et al., 2011), although further efforts are required to obtain biochar with suitable properties (Manyà, 2012). One of the attractive characteristics of biochar as a soil amendment is its porous structure, which improves water retention and increases soil surface area (Sohi et al., 2009). Moreover, the concentration of biochar into soil has been related to an improved nutrient use efficiency, either through nutrients contained in biochar or through physicochemical processes that allow a better uptake of soil-inherent or fertilizer-derived nutrients (Sohi et al., 2009). The application of biochar increases physical and chemical qualities of soils, resulting in greater productivity of the agro-ecosystem (Laird et al., 2010). Biochar, due to its biological and chemical stability, can also act as a C sink. The recalcitrance of biochar to microbial degradation enables the long-term sequestration of C in soil (Sohi et al., 2009; Lehmann, 2007).

Cited article

Zambon, I., Colosimo, F., Monarca, D., Cecchini, M., Gallucci, F., Proto, A.R., Lord, R., Colantoni, A. (2016). An Innovative Agro-Forestry Supply Chain For Residual Biomass: Physicochemical Characterization Of Biochar From Olive And Hazelnut Pellets. Energies 9 (7), 526.

Biochar application in agriculture, positively affects the water holding capacity; this property derives from the distribution and the degree of cohesion of the pores in biochar, which depends on the particles size and aggregation, as well as the organic matter (OM) content. The effect of biochar on water holding capacity is dependent on both the high internal surface area of biochar and the capability to aggregate soil particles with OM, minerals, and microorganisms. The increase in soil porosity also allows a better percolation of excess water towards the deeper layers of the soil, therefore increasing ventilation.

Biomass residues in Mediterranean areas come mainly from agricultural and agro-industrial activities, as well as forest by-products. Only a few woody residues are used to produce fertilizers and as renewable energy resources (Di Giacomo and Taglieri, 2009). In contrast, typical management strategies in the agricultural industry do not provide any valorization of these biomasses, which are burnt in the field to

prevent proliferation of plant diseases (Di Giacomo and Taglieri, 2009). However, this landfill choice affects the soil structure since OM in woody biomass residues must be completely decomposed before used as fertiliser.

8.2.1. Biomass from olive and hazelnut pruning

In the area of Viterbo, pruning residues from olive and hazelnut are rarely utilized as a source of energy in burning stoves or boilers; they are, instead, burnt in situ, therefore reducing the formation of soil organic carbon. During summer, besides pruning residues, suckers are removed before the harvest, representing another significant loss of biomass. Approximately 15 m3 of biomass samples from both olive and hazelnut have been collected in farms of the Viterbo province. Recent studies (Di Giacomo and Taglieri, 2009; Colantoni et al., 2015c; Di Giacinto et al., 2014) have investigated the possibility of enhancing olive and hazelnut residue waste management to produce soil fertilizers and energy, therefore reducing the environmental impact of such residual organic wastes. Biomass from pruning crop operations (Figure 8.5a, b) represents an attractive resource that could be exploited for (i) fuel production (combustion and/or gasification) and (ii) biochar production (pyrolysis) that can be used as soil fertilizer. A pelletization procedure was developed and applied on bio-shredding obtained from olive and hazelnut residues (Figure 8.5c).

Figure 8.5. Pruning residues from (a) olive and (b) hazelnut after crop operations; and (c) bio-shredding.

Pruning residues were collected on site and immediately transferred to the laboratory for sifting and exsiccation (Figure 8.6) until a water content of 15% was achieved. Final water content as low as 15% is necessary for further refining of the product and pellet production. The humidity concentration in the prunings is very notable. In Italy there are not many companies and total supply chains that work the prunings for pellet production and for use of these residual agriculture sub-products (Figure 8.7).

Figure 8.6. Schematic of the pelletization process showing (a) pellet mill; (b) olive and hazelnut pellet; and (c) packaging.

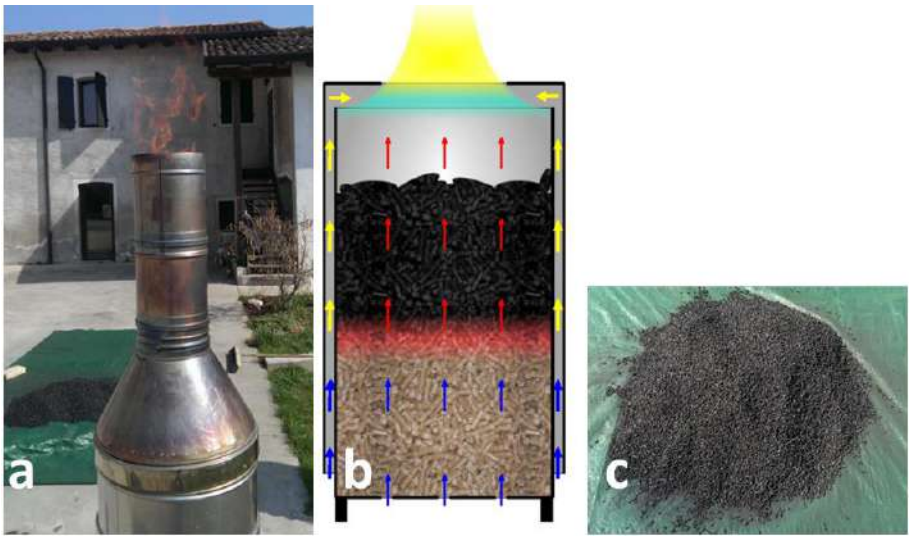


Figure 8.7. Biochar production from pellets showing (a) the Elsa Research carbonization system; (b) a schematic representation of the conversion process; and (c) the final product (biochar).

8.2.2. Pyrolysis process

Pyrolysis of biomass is commonly considered as a thermo-chemical conversion process (Panwar et al., 2012; White et al., 2011). Pyrolysis is carried out under partial (or complete) absence of oxygen and relies on capturing the off-gases from thermal decomposition of the organic materials (Lehmann, 2007). The physicochemical characteristics of biochar are determined by the type of feedstock and by the temperature of pyrolysis. For example, higher salt and ash contents are expected in wheat straw than in wood-derived biochar (Kloss et al., 2012) and C content and N content are greater in pine chips than in poultry litter-derived biochar (Gaskin et al., 2008). A higher pyrolysis temperature results in greater surface area, lower biochar recovery, higher ash content, elevated pH, minimal total surface charge (Novak et al., 2009), and lower cation exchange capacity (Kloss et al., 2012). Removal of volatile compounds at higher pyrolysis temperatures also cause biochars to have higher C content and lower hydrogen (H) and O content (Novak et al., 2009). Pyrolysis of agro-forestry residues is typically carried out with temperatures between 400 and 800 °C. With these conditions, the feedstock is converted to liquid products (so-called tar or pyrolysis oil) and/or gas (syngas), which can be used as fuels or raw materials for subsequent chemical transformation. The residual solid carbonaceous material obtained (biochar) could be further refined to products, such as activated carbon.

8.2.3. Biochar production form olive and hazelnut pellets

The carbonization system Elsa Research (Blucomb Ltd., based in Udine, Italy) was used to produce the biochar from olive and hazelnut pellets; biomass conversion was achieved by pyrolytic micro-gasification. The Elsa Research carbonization system works with natural ventilation and does not require being powered by batteries or electricity. A chimney is typically used to increase the air draft for fuels that have difficulties igniting.

Physicochemical characterization of the biochar obtained from the Elsa Research carbonization system was performed at the European Biochar Institute, which released the EBC based on the quality of the biochar.

8.2.4. Conversion rates analyses from biomass to biochar

Auto-thermal conversion of biomass was carried out under natural ventilation. Quantitative analyses of pyrolysed biomass and produced biochar, as well as the conversion rates, are reported for 10 and four sessions of pyrolysis, respectively, for olive and hazelnut pellets (Table 8.1). A statistical comparison

between olive and hazelnut performances during pyrolysis is reported in Table 8.2, showing the total conversion rates, mean, and standard deviation (SD) of the results obtained in the experiments.

Table 8.1. Conversion rates of biomass obtained from each pyrolysis session.

Olive				Hazelnut			
Session	Biomass (kg)	Biochar (kg)	Conversion Rate	Session	Biomass (kg)	Biochar (kg)	Conversion Rate
1	38.35	8.11	0.209	1	37.69	8.11	0.215
2	39.07	8.21	0.210	2	36.25	7.96	0.220
3	38.88	8.19	0.211	3	37.03	8.09	0.218
4	38.96	8.16	0.209	4	37.11	8.09	0.218
5	34.09	7.10	0.208				
6	39.02	8.23	0.211				
7	38.89	8.19	0.211				
8	38.93	8.19	0.210				
9	38.97	8.20	0.210				
10	38.81	8.13	0.209				

Table 8.2. Comparisons and statistical values of conversion rates of olive and hazelnut.

	Olive		Hazelnut	
	Biochar (kg)	Conversion Rate	Biochar (kg)	Conversion Rate
Total	384.47	80.71	148.08	32.25
Mean		0.210		0.218
SD		0.00088		0.00188

Further analyses were carried out to investigate the calorific power of the two biochars produced. Composition, structure, heat value of the gas, tar liquid, and semi-char solid products depend on the pyrolysis temperature (Panwar et al., 2012). Quantity and quality of resulting outputs from biomass pyrolysis are related to the chemical composition of the operating temperature and the feedstock (Panwar et al., 2012; Ceylan and Bredenberg, 1982). The calorific values calculated were compared with those provided by the producers to make energy considerations on the process. The results obtained are consistent with other pyrolysis processes. The latter led to the volatilization of a fraction of biomass with a calorific value ranging between 75% and 85% of the starting biomass. The calorific value is measured in terms of the high calorific value (Jothibasu and Mathivanan, 2015). Table 8.3 distinguishes two types of calorific value (usually expressed in MJ/kg): (i) the higher calorific value that it is the amount of heat produced by a complete combustion of a mass unit of a sample, at constant volume, in an atmosphere rich of oxygen at standard conditions (25 °C, 101.3 kPa); and (ii) the lower calorific value (PCI) that does not include the heat of the condenzation of water (Jothibasu and Mathivanan, 2015).

Table 8.3. Analysis of the calorific power of pyrolysis reaction for the two biochars produced.

Olive Wood	Units	Pellet	Biochar
Higher calorific value	MJ/kg	19.47	31.71
Lower calorific value	MJ/kg	16.17	30.48
Calorific value from pyrolysis	MJ/kg	12.37	
Percentage of calorific value from pyrolysis	%	0.76	
Hazelnut Wood	Units	Pellet	Biochar
Higher calorific value	MJ/kg	19.02	26.62
Lower calorific value	MJ/kg	16.71	25.66
Calorific value from pyrolysis	MJ/kg	14.21	
Percentage of calorific value from pyrolysis	%	0.85	

Pyrolysis does not produce energy from heat; rather, it leads to the production of gas from biomass. In general, pyrolysis involves the heating of biomass to temperatures greater than 400 °C in the absence of oxygen (Laird, 2008).

At these temperatures, biomass thermally decomposes releasing a vapor phase and biochar (solid phase). On cooling the pyrolysis vapour, polar and high-molecular-weight compounds condense out as bio-oil (liquid phase) while low-molecular-weight volatile compounds remain in the gas phase (syngas) (Hoogwijk et al., 2003). The physics and chemistry of pyrolysis process results are extremely complex and are dependent depending on both the rector conditions and the nature of the biomass (Laird, 2008). The combustion of gas in the Elsa Research system occurs in "close-coupled combustion" (micro-gasification). Biochars produced by Blucomb Ltd. (Udine, Italy) (spin-off) for the European project were analyzed by Eurofins laboratories, accredited for the certification of the EBC. International biochar experts developed the EBC to consider it in the European context as a voluntary industrial standard (European Biochar Certificate, 2012). The EBC guarantees a sustainable biochar production, with a low-risk use in agronomic systems. Biochar produced in accordance with the standards of the EBC fulfils all the requirements of sustainable production and environmental impact by certifying (i) sustainable production and provision of biomass feedstock; (ii) energy efficient, low emission pyrolysis technique; (iii) low contaminant level in the biochar; and (iv) low hazard use and application of the biochar. These standards follow current environmental European regulations.

8.2.5. Elemental analysis

The chemical composition of biochar is determined also by the source of biomass employed. Biochar produced from wood, for example, is denser and has higher C content (80%) (Demirbas, 2004). These properties reflect the chemical complexity of lignin, which makes it more resistant to thermal degradation. The elemental composition, plotted as H/C vs. O/C ratios (Figure 8.8), is often used to describe maturity, decomposition rate, and combustion behaviour of fossil chars and coal (Hammes et al., 2006; Krevelen, 1957). When applied to biochar, the H/C and O/C ratios can be suitable indicators of the degree of carbonization. High ratios typically point to primary plant macromolecules, such as simple carbohydrates and cellulose (Chun et al., 2004). An H/C ratio of ≤0.2 indicates C of plant origin with elevated carbonization (Kuhlbusch and Crutzen, 1995).

The O/C ratio is an indicator of the presence of polar functional groups, which influence the stability of biochar by preventing a dense, graphite-like structure of the material (Laine and Yunes, 1992). Therefore, the O/C ratio is useful to assess hydrophilicity and hydrophobicity of the charred material. The ratios of H, O, and C can also be used to differentiate between materials obtained by different processes. In the view of C sequestration and for material with complex aromatic structure and low presence of functional groups, optimum ratios of H/C and O/C are approximately ≤0.6 and ≤0.4, respectively (Schimmelpfennig and Glaser, 2012). Nitrogen in biochar is an important nutrient, its concentration is related to the concentration in the starting material, with values between 1.8 and 56 g·Kg−1, although N in biochar is in a form often not readily bioavailable (Chan and Xu, 2012). The C/N ratio, an indicator of the bioavailability of an organic compound, is highly variable and ranges between 7 and 500 (Schimmelpfennig and Glaser, 2012).

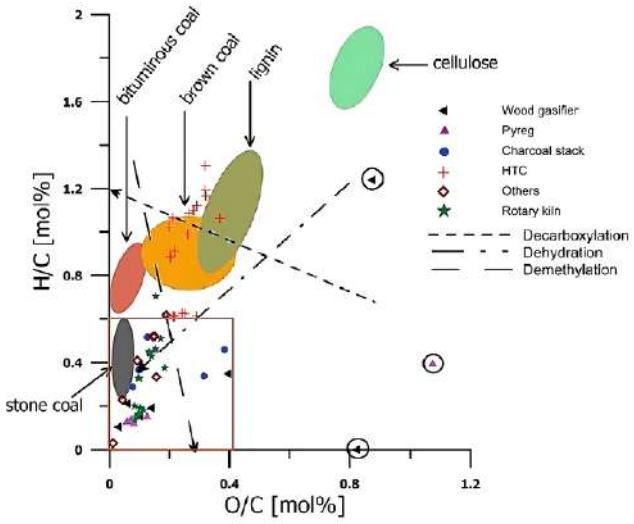


Figure 8.8. Example of Van Krevelen diagram of biochars obtained through different pyrolisis processes. The red square shows the optimum elemental ratio values of H/C and O/C for biochar production.

The results of elemental analyses of the two biochars investigated are reported in Table 8.4. Both biochars are characterized by values well below the limits established by the EBC, particularly the olive and hazelnut biochars have high values of C and low H/C and O/C ratios. A low H/C ratio indicates that the produced biochars are also recalcitrant to microbial degradation. These results indicate that the production process yield high-quality biochars with a level of carbonization that makes it suitable for C sequestration, as confirmed by the H/C ratios.

Table 8.4. Elemental analyses from EBC (Method DIN 51732).

Elements	Units	Hazelnut Biochar	Olive Biochar	EBC Biochar Base	EBC Biochar Premium
H (Hydrogen)	% w/w	1.21	1.58	-	-
C (Carbon, total)	% w/w	78.1	90.1	>50	>50
N (Nitrogen, total)	% w/w	0.64	0.42	-	-
O (Oxygen)	% w/w	1.2	1.7	-	-
Carbonate as CO_2	% w/w	2.62	1.17	-	-
Carbonate (organic)		75.5	89.8		
H/C ratio (molar)		0.18	0.21	<0.6	<0.6
O/C rate (molar)		0.012	0.014	<0.4	<0.4
Sulphur (total)	% w/w	0.07	<0.03		

8.2.6. Nutrients and trace elements

Biomass residues containing high concentrations of minerals, such as those obtained from herbaceous plants produce biochars with high ash content (Demirbas, 2004), maintain in the biochar matrix most of the nutrients present in the starting material (Table 8.5). These types of biochar have a lower total carbon (TC) content and cohesion than those obtained from wood-pruning biomass. The low C content, together with elevated concentrations of nutrients, makes biochars from herbaceous material more readily available for microorganisms (Sohi et al., 2009). The concentration of phosphorus (P) and potassium (K) in the biochar is related to the initial content in the feedstock. The content of P and K are typically between 2.7 and 480 g·kg−1 and 10 to 58 g·kg−1, respectively (Chan and Xu, 2012).

Table 8.5. Determination from microwave digestion (method: DIN 22022-1).

Elements	Units	Methods	Hazelnut Biochar	Olive Biochar	EBC Biochar Base	EBC Biochar Premium

P (Phosphorus)	mg/kg	ISO 11885	590	330	-	-
Mg (Magnesium)	mg/kg	ISO 11885	2900	1400	-	-
Ca (Calcium)	mg/kg	ISO 11885	38000	11000	-	-
K (Potassium)	mg/kg	ISO 11885	5500	3500	-	-
Na (Sodium)	mg/kg	ISO 11885	2100	260	-	-
Fe (Iron)	mg/kg	ISO 11885	6500	1500	-	-
Si (Silicon)	mg/kg	ISO 11885	25000	9700	-	-
S (Sulphur)	mg/kg	ISO 11885	910	200	-	-
Pb (Lead)	mg/kg	ISO 17294-2	66	20	<150	<120
Cd (Cadmium)	mg/kg	ISO 17294-2	<0.2	<0.2	<1.5	<1
Cu (Copper)	mg/kg	ISO 17294-2	100	6	<100	<100
Ni (Nickel)	mg/kg	ISO 17294-2	9	8	<50	<30
Hg (Mercury)	mg/kg	DIN EN 1483	<0.07	<0.07	<1	<1
Zn (Zinc)	mg/kg	ISO 17294-2	340	84	<400	<400
Cr (Chromium total)	mg/kg	ISO 17294-2	22	15	<90	<80
B (Boron)	mg/kg	ISO 17294-2	32	10	-	-
Mn (Manganese)	mg/kg	ISO 17294-2	350	380	-	-

EBC biochar base and premium report the limits required by the EBC protocol of certification. The total ash content ranged between 6.2% and 18.8% (w/w) for biochar from pellets of olive and hazelnut wood. The nutrient content is much greater in hazelnut biochar than olive, which was evident especially for Mg, Ca, Fe, S, Cu, and Zn. Biochar from hazelnut pellets could bring a greater contribution of nutrients to the soil and, therefore, be less resistant to microbial decomposition. Heavy metal content in both biochars was well below the EBC limits. Only Cu in the hazelnut biochar was close to the maximum value established by the EBC.

8.2.7. PAHs Composition

Polycyclic Aromatic Hydrocarbons (PAHs)are ubiquitous in the environment, being by-products of the incomplete combustion of organic material (Keith and Telliard, 1979). The chemical structure of PAHs makes them highly resistant to biodegradation and oxidation (Preston and Schmidt, 2006). The presence of PAHs in pyrolytic reactions above 700 °C is well established (Ledesma et al., 2002), although they can be produced in pyrolysis reactions of less than 700 °C at low concentration (Garcia-Perez, 2008). It is, therefore, critical to ensure PAH concentrations remain below the limits established by the EBC. The 16 priority US EPA PAHs are typically used to assess the total PAH content; the limits established by the EBC are of <12 and <4 mg/kg for biochar standard and premium, respectively. The PAH composition of the two biochars analyzed (Table 8.6), shows that both biochars are well below the EBC limits, with values ranging from <0.1 to 1.1 mg/Kg.

Table 8.6. PAHs determination from toluene extract.

Elements	Units	Methods	Limits		Hazelnut Biochar	Olive Biochar
			GW 1 *	GW 2 *		
Naphthalene	mg/kg	DIN EN 15527	-	-	0.9	1.1
Acenaphthylene	mg/kg	DIN EN 15527	-	-	<0.1	<0.1
Acenaphthene	mg/kg	DIN EN 15527	-	-	<0.1	<0.1
Fluorene	mg/kg	DIN EN 15527	-	-	<0.1	<0.1
Phenanthrene	mg/kg	DIN EN 15527	-	-	0.3	0.3
Anthracene	mg/kg	DIN EN 15527	-	-	<0.1	<0.1
Fluoranthene	mg/kg	DIN EN 15527	-	-	0.1	0.1

Pyrene	mg/kg	DIN EN 15527	-	-	0.1	0.1
Benz(a)anthracene	mg/kg	DIN EN 15527	-	-	<0.1	<0.1
Chrysene	mg/kg	DIN EN 15527	-	-	<0.1	<0.1
Benzo(b)fluoranthene	mg/kg	DIN EN 15527	-	-	<0.1	<0.1
Benzo(k)fluoranthene	mg/kg	DIN EN 15527	-	-	<0.1	<0.1
Benzo(a)pyrene	mg/kg	DIN EN 15527	-	-	<0.1	<0.1
Indeno(1,2,3-cd) pyrene	mg/kg	DIN EN 15527	-	-	<0.1	<0.1
Dibenz (a, h) anthracene	mg/kg	DIN EN 15527	-	-	<0.1	<0.1
Benzo (g, h, i) perylene	mg/kg	DIN EN 15527	-	-	<0.1	<0.1
SUM PAHs (EPA)	mg/kg	calculated	<12	<4	1.20	1.60

Total PAH content of the two biochars are 1.2 and 1.6 mg/kg for olive and hazelnut, respectively. Therefore, both biochars can be considered suitable for soil applications, since both are well below the EBC threshold limit of 4 mg·kg for biochar premium.

8.2.8. pH, Electrical Conductivity and Density

In general, the pH of biochar is relatively homogeneous and varies from neutral to basic pH. Feedstock of various origins produce biochar with an average pH between 6.2 and 9.6 (Chan and Xu, 2012). Lower pH is typically found for biochars obtained from green pruning feedstock and organic waste, while the highest values are to be attributed to poultry litter biochar. Table 8.7 reports the elements values, according to their pH, electrical conductivity (EC), salt content and density.

Table 8.7. Elements value (pH, electrical conductivity, and density).

Elements	Units	Hazelnut Biochar	Olive Biochar
pH values ($CaCl_2$)	-	9.9	8.4
EC	µS/cm	332	217
Salt content	g/kg	0.655	1.18
Salt content cal. with bulk density	g/L	0.287	0.527

The two biochar have a pH of 8.4 and 9.9 for olive and hazelnut, respectively. The EBC indicates a maximum limit of 10; therefore, biochar produced from these types of wood residues is slightly below the limit established by the certification. The EC is of particular importance when adding biochar to soils with high EC and salinity. The two biochars had an EC of 217 and 332 mS/cm, respectively, for olive and hazelnut (as shown in Table 7). Both values are very low and do not represent a real risk for the addition to soil even under conditions of high EC. In general, biochar has a lower density than soil, with an average of 0.4 g·cm−3 compared to a soil of medium texture, with average of 1.3 g·cm−3. When adding biochar to soils with little ventilation, this property can help to reduce the density by mitigating issues related to the compaction of soil. The olive and hazelnut biochars produced have a density of 0.45 and 0.44 g·cm−3, respectively.

8.2.9. Agro-forestry chain for high-quality biochar

The two biochars analyzed show excellent physicochemical properties, which makes them suitable for agricultural applications. Both biochars can be certified as Biochar Premium according to the regulations of the EBC; this allows a potential commercialization of the biochars, with higher prices than Biochar Base, typically less expensive, but with a higher content of PAHs. The benefits of using Biochar Premium as soil fertilizer includes improved productivity, increased water holding capacity of the soil (Fellet et al., 2011; Karhu et al., 2011; Streubel et al., 2011), and a better retention of nutrients and agrochemicals in soils, all of which should offset initial investment and provide added profits per application. Biochar fuel commands a high-value application, offering numerous benefits, and an authentic alternative to develop the biomass utilization efficiency (Anupam et al., 2016; Liu et al., 2013). The added value of biochar is also linked to

other issues, such as those involving agricultural and environmental sustainability. As claimed by many studies (Lehmann and Stephen, 2009; Agegnehu et al., 2015), biochar as a soil amendment can improve soil health and increase agricultural productivity with further environmental benefits related to global warming mitigation (Agegnehu et al., 2015; Reza et al., 2014; Hill et al., 2006; Chandra et al., 2012; Kim et al., 2015; Civitarese et al., 2015).

8.3. Building supply chain energy opportunity

In recent decades, the traditional use of biomass for the paper market has been accompanied by increasing demand in the energy sector (Lauri et al., 2014; Olorunnisola, 2007; Silver et al., 2015). The production of biomass for the energy industry is associated with specific silviculture (Colantoni et al., 2016b; Martire et al., 2015a; Fischer et al., 2017; Galik et al., 2016), which is very often linked to artificial reforestation rather than to the development of natural forests (Martire et al., 2015b). In recent years, many studies have focused on bioenergy plants (Colantoni et al., 2016a; Giwa et al., 2017; Martire et al., 2015a; Sharma et al., 2016; Silver et al., 2015; Monarca et al., 2008, 2011, 2012). However, very often, only various aspects are considered, e.g., with engineering or energy performance nature, without understanding the impact that a bioenergy plant can generate in the surrounding area. Regarding bioenergy, it is indispensable to evaluate the (natural) resources available in the given region guaranteeing an adequate degree of environmental sustainability. The recovery of biomass for energy purposes is conditioned by many limiting factors, e.g., (i) difficulties in recovering (also residual) biomass and mechanizing harvesting; (ii) the absence of an industrial dimension; (iii) limits imposed by forest management rules, which in some cases prevent the recovery of the trash, and (iv) procurement costs (Colantoni et al., 2016a, b; Daioglou et al., 2016; Speirs et al., 2015). The first phase is to estimate the potential biomass that a definite area can assure, and therefore enable a suitable sustainable development. Then, the economic sustainability of the biomass plant, with its technical characteristics and performance, was calculated. Through a supply chain based on local fuel production capacity, innovative opportunities can be built by reusing biomass, which can be considered agricultural and forestry waste, and providing long-term job opportunities through a reliable and efficient bioenergy plant (both in economic and energy terms).

Cited article

Bonazzi, F. A., Cividino, S. R., Zambon, I., Mosconi, E. M., Poponi, S. (2018). Building Energy Opportunity With A Supply Chain Based On The Local Fuel-Producing Capacity. Sustainability, 10(7), 1-15.

There are two statistical sources in Italy that provide information on forests: The National Forest Inventory (NFI) and National Institute of Statistics (ISTAT). The forest heritage of the Lazio region accounts for about 5% of the entire national forestry in Italy. The most affected areas are the Apennine and pre-Apennine ridge in Italy, which are mainly located in the marginal and internal areas of hills and mountains (Colantoni et al., 2016a). As exposed by the recent Energy Plan of the Lazio Region adopted in 2017, the quantities of biomass (such as forest pruning) available in the provinces of Rieti, Viterbo, and in the northern area of Rome are mostly adequate to establish a local supply chain based on the use of biomass to produce energy. About 25% of the forest cover is in the province of Rieti. Owing to the incidence of rich aquifers at minimum depths (Martini, 2017; Tassi et al., 2014) and the current crisis of traditional crops (Biasi et al., 2015; Clemente et al., 2017; Gobattoni et al., 2015), these contexts in the Lazio region own model topographies for developing energy crops, and thus agroenergy districts (Colantoni et al., 2016a).

Italy has adopted many strategies toward sustainable development in recent years, including the use of renewable resources, e.g., biomass (Zambon et al., 2016b). With the aim of protecting the surrounding environment, the most efficient technologies available by examining the experiences of small-scale local installations were detected (Zambon et al., 2017a; Boubaker et al., 2015). The present work was based on an innovative framework based on the design of a complete plant for the energy production with a net power output of 4 MWe, which essentially consists of a combustion furnace with a mobile grid integrated by a superheated steam Rankine cycle (Hirn cycle), at an industrial site of the municipality of Rieti (Italy). The proposed plant is powered by combustible biomass (defined by the DPCM (Ministerial Decree) March 8, 2002 and modified by the DPCM 08/10/2004) with reference to biomass waste from agricultural, forestry, forestry and agro-industrial activities, and energy crops (short rotation forestry) treated exclusively with

mechanical systems. The chief aim is to offer a complete investigation starting from a geographical analysis of the context, as it is often underestimated in earlier studies (Zambon et al., 2017d; Macrì et al., 2016), moving to engineering, technical, economic and environmental measures (Martire et al., 2015a; Manos et al., 2014; Monarca et al., 2011, 2012) so that the plant is really functionable. A strong focus was provided on two key themes for the plant: (i) biomass availability in the local contexts; and (ii) a feasibility study. Further objectives emerge such as that (i) the flue gas treatment system for the abatement of pollutants complies with the most restrictive requirements imposed by the regulations in force; that (ii) the ash and dust extracted are subjected to an inertization process and that (iii) all of the waste and meteoric water is collected and conveyed to the consortium purifier. Particularly, safeguarding the surrounding environment as far as the emission of pollutants is concerned, the plant was designed using the most efficient technologies with the objective of reducing pollutants and complying with the most restrictive requirements imposed by the current legislation.

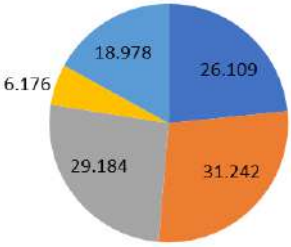
Lastly, previous works habitually focused on monothematic subjects, e.g., studying bioenergy plants in terms of engineering or energy performance without weighing their socio-economic and environmental impacts (Colantoni et al., 2016b; Giwa et al., 2017; Martire et al., 2015b; Sharma et al., 2016; Silver et al., 2015; Monarca et al., 2008, 2011, 2012). Therefore, three tasks can be detected with the aim of: (i) assessing the biomass potential from a sustainable perspective; (ii) providing an economic accounting of an exemplary biomass plant in terms of its technical characteristics and performance; and (iii) evaluating social and environmental impacts.

8.3.1. Regional Energy Plan

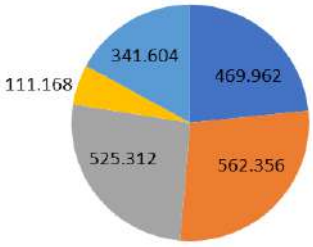
By means of Regional Council Resolution no. 656 of 17 October 2017 (published in the Official Bulletin of the Lazio Region or BURL of 31 October 2017, No. 87, Suppl. Nos. 2, 3, and 4), the proposal for a "Regional Energy Plan" (P. E. R. Lazio) was adopted in the Lazio region. Biomasses can assume a crucial role in this plan. The main types of biomasses are related in this Italian region to: agricultural and agro-industrial residues (grass, pruning, shells, pomace); forestry; and fermentable residues (pigs, cattle, cattle, slaughter waste, organic fraction).

In the present work, data relating to the potential availability of biomass was obtained from evaluations contained in several databases: (i) the Atlas of Biomasses about agricultural, agro-industrial, forestry, and fermentable residues excluding the organic fraction from municipal waste; (ii) the Regional Waste Plan, especially of the Lazio region; (iii) the Institute for Environmental Protection and Research (ISPRA) Waste Report; and (iv) the determination of vital requests (e.g., about the organic fraction of municipal waste and the fraction of waste sent to landfill). Furthermore, potentials of forestry biomass are reported from National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA) data processing, describing the gross and net availability of current uses in terms of dry matter and disjointed energy potential at the provincial level (Figure 8.9).

Total forest biomass (ton/year)



Total (GJ)



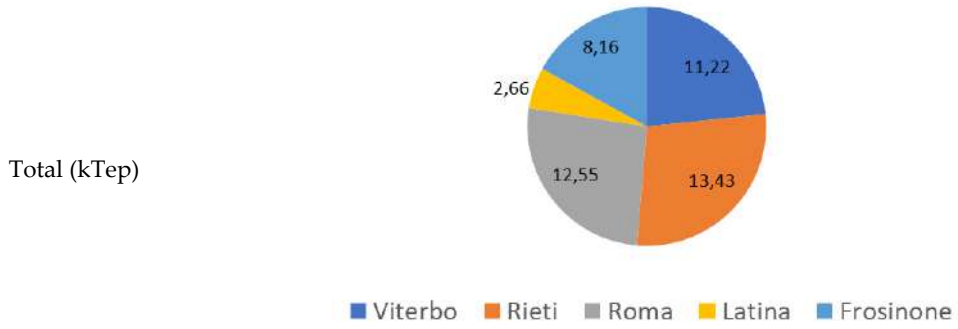


Figure 8.9. Gross potential for forestry biomass in each province of the Lazio region expressed in ton/year, GJ, and kTep. Source: elaboration from ENEA, Atlas of Biomasses.

8.3.2. A supply chain energy based on the local fuel-producing capacity

The research design concerns a plant to produce electricity, with a net power output of 4 MWe, fundamentally consisting of a combustion furnace with a movable grill integrated by a superheated steam Rankine cycle (Hirn cycle). As defined by the DPCM 8 March 2002 and modified by the DPCM 8 October 2004, the plant proposed can be fed by combustible biomass waste from agricultural, forestry, and agro-industrial activities obtained from local primary sector activities, and from specific energy crops treated exclusively with mechanical systems. The main types of biomass that may be used as fuel are: natural wood from silvicultural activities and forest maintenance, e.g., pruning of trees (e.g., olive groves); herbaceous residues from agricultural activities; hazelnuts and fruit shells (typical local cultivation); virgin and spent olive pomace from the activities of olive mills; sawdust, bark, shavings, chips, panels, veneers, and waste from primary and secondary wood processing (not chemically treated); and natural wood from poplar crops with annual and/or biennial rotation.

The investigated area initially covered the whole Province of Rieti. The latter area is an Italian central province situated in the Lazio region that has Rieti as its capital city, covering an area of about 3000 km ^{2} and including 73 municipalities. Envisaging the greatest location required considering which area could ensure a sufficient amount of biomass for energy sustainability and the operation of the plant. Considering the Energy Plan of the Lazio Region, the quantities of lignocellulosic biomasses (e.g., forest pruning, e.g., olive groves) available in the Province of Rieti are largely sufficient to feed the plant. In fact, following the inventory of National Forest Inventory (NFI) and ISTAT, about 25% of the forest cover of the Lazio region is in the province of Rieti, which is situated in the central area of Italy (Figure 8.10). The Province of Rieti has a mainly mountainous orography that is characterized by the presence of gorges, valleys, and plains. It is one of the richest Italian territories in water due to the number of lakes and rivers inserted in an environment characterized by woods, hills, and plains. The Province of Rieti, e.g., due to the water presence and the state of crisis of traditional crops, has ideal features for developing energy crops. Finally, the location of the plant was assumed to be in an industrial site in the province of Rieti. The location of the plant makes it possible to optimize the distribution of biomass to be used as energy fuel, both in terms of quantity and transport logistics.

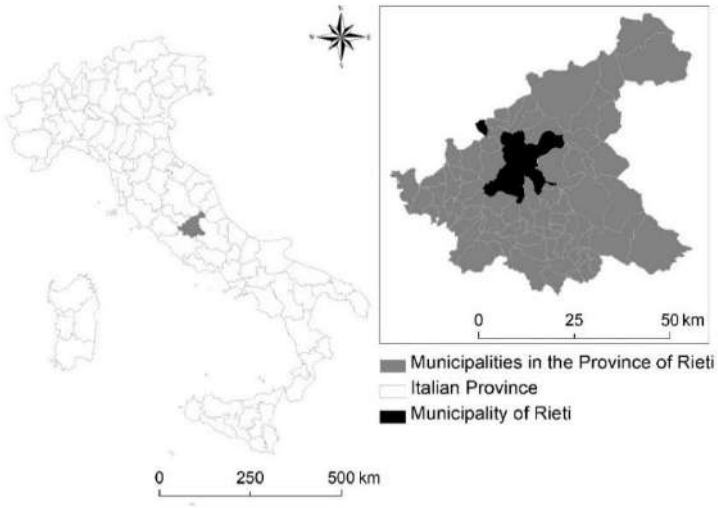


Figure 8.10. Territorial framework studied.

The spatial evaluation was developed at the municipal scale based on a GIS procedure, provided by the arcMap program of ESRI (Zambon et al., 2017a). Thanks to GIS technologies and official national documents, the optimal area can identify where place the proposed plant. Estimating how much biomass the territory can offer, optimizing energetic and even logistic processes, the provisions of the plan were designed for almost 60,000 tons of fuel where the chemical and physical characteristics are consistent with modern steam-producing boilers. The supply plan defines a mixture of local vegetal biomass made of fruit and olive tree thinning, waste matter from urban green areas, matter from forest handling, and poplar harvesting, according to short rotation forestry (Kruse et al., 2003; McKendry, 2002). The territorial analysis was carried out for each one of the tree components. In this way, it is possible to identify the ideal context in which to locate the plant.

8.3.3. Economic and financial examination

Assessing the economic and financial performance, the following concepts will be applied in this research. Economic and financial investigation enabled estimating the calorific value (CV), price, and energy price, along with the resulting costs and consumption. Assuming the necessary quantity of biomass per year and the installable power, the size of the plant and therefore also the investment cost that should be sustained were projected. Furthermore, other key indicators were calculated, such as: electric energy (EE), selling price (€/MWh), and unit investment (both in €/kW and €/kWh).

The resulting return on equity (in percentage terms) can be incorporated in the fundamental concept of the finance of the WACC, which defines the weighted average of the cost of capital coming from both the equity and the debt (Farber et al., 2006; Ondraczek et al., 2015). The internal rate of return (IRR), the payback period, and the net present value (NPV) were calculated. Precisely, the work also applied the following formulas and definitions: (i) EBITDA (earnings before interest, taxes, depreciation, and amortization), which offers the ability to generate an economic margin in percentage terms by considering financial policies (interest income and expense) and budget techniques (e.g., amortization, depreciation, and taxation). It is indispensable for profitability analysis at a management level to estimate the profitability of an investment and assists in the comparison of results from different businesses operating in the identical economic sector. Its application for each year (n) is specified according to the following equations:

$$\text{EBITDA (n)} = \text{Added value (n)} - \text{Cost of employees (n)}$$

$$\text{EBITDA \%} = \text{EBITDA (n)}/\text{Revenues (n)} \times 100$$

Then, (ii) the debt service coverage ratio (DSCR) was run to calculate the annual capacity of an activity

to cover its debts, therefore highlighting how much of the investment can be financed through a financial structure (known as the bankability of the project):

$$DSCR = FCO/ (Df (n) + I (n))$$

where 'FCO' is the cash flow; 'Df' is the principal repayments; 'I' represents the interest payments; and 'n' is the ith year. Furthermore, DSCR can assume different values: >1 (positive capacity), or <1 (negative capacity) to finance the investment of expertise in n year.

The payback period embodies the number of years that are required to offset the investment. The payback period of a given investment (or project) is a central determinant of whether to proceed with the project, as longer payback periods are characteristically not desirable for investment positions. The examination was founded on the calculation of net present value (NPV) as the fundamental tool for choosing the optimal investment. This technique was applied to correlate the value of the plant with the ability to produce a level of financial flow that was adequate enough to meet an investor's expectation of remuneration. The calculation was applied in the classical formula: where NCF are the cash flows from operating activities; t is n years of investment; and r is the discount rate.

From the logistical standpoint, a transportation radius was calculated to cover all of the biomasses present in Rieti and the surrounding municipalities. Transport costs have been estimated in this way. Furthermore, additional charges were assessed, such as the average price Green Certification (€/MWh), hypothesis price (€/MWh), concessions (€), and other costs and expenses (€), which involve maintenance, oil, water, insurance, etc.

The economic analysis has also made it possible to estimate: (i) the social impact, in terms of new jobs and thus granting new employment opportunities in Rieti; and (ii) an environmental influence to ensure adequate sustainable development, using renewable energy resources from the surrounding territory that are not of fossil origin.

8.3.4. Biomass availability

The proposal was the production of 24 MW of project thermal power and 4 MW of project electric power. The resulting plant was then reviewed from the viewpoint of the norms providing for renewable energy, environmental consistency, and emissions into the atmosphere.

Integrating the three databases (NFI, ISTAT, and the 2017 Energy Plan of Lazio Region), the potentially available biomass was identified at the municipal scale. The territorial analysis allowed detecting where the biomass is placed and its nearness to the bioenergy plant, with the aim of optimizing even the logistical processes. Forest assortments derive primarily from conifer wood (about 1287 tons). The studied plant can used waste material from poplar cultivation (143 tons), beech trees (143 tons), deciduous trees (excluding poplar and chestnut trees) (53 tons), and castanets (884 tons). Given the relevant amount of biomass available, it can be stated that the bioenergy market in Rieti is sufficiently competitive, particularly at the regional scale but also at the national level, since the energy plant avails sufficient biomass to properly operate over time. Furthermore, the operators who will work in this plant will enjoy a continuous work activity over time, also allowing new employment opportunities in the primary sector. The territorial analysis of where to place the plant was carried out with the elaboration of statistical data and GIS programs provided by ESRI. The analysis brought to light a fragmented spatial reality consisted by many villages located in the mountains in the province of Rieti. This situation makes clear the determination of two indicative peculiarities: (i) prevalently mountainous territory, with some hilly parts; and (ii) in a total of 73 municipalities in the province of Rieti, only four municipalities (Rieti, Poggio Mirteto, Fara in Sabina, and Cittaducale) exceed 5000 inhabitants, resulting from a typical mountain context.

Estimating the total amount of forestry biomass that is available and theoretically usable for energy

purposes in the province of Rieti, the analysis excluded municipalities with a percentage ratio among the forest area and the municipal area that was less than 20%. For them, biomass concentrations are inadequate to rationalize the cost-effectiveness of large-scale biomass energy use. Then, all of the surfaces with resinous woodlands were removed, partly since they have a protection function, and therefore may only undergo slight operations. Also, municipalities with a total available biomass of less than 1000 t/year have been rejected. The final data found for each municipality pointed out that the total quantity of biomass available throughout the provincial territory is approximately 238,000 t/year. For instance, following the Regional Energy Plan, Rieti and Cittaducale occupy municipal areas of 20,652 hectares and 7095 hectares, respectively, offering about 24,906 and 8442 t/year.

8.3.5. Feasibility study

Due to its ideal features, the plant was designated in the municipality of Rieti, as this municipality allows economic optimization, greater available resources, local nearness and compactness for users, and low transport costs. Biomass quantities can be withdrawn from the forest sector in a hypothesis of adequate exploitation of the resources that are present in the municipality of Rieti, with a target price that is lower than the price of firewood, but still adequate to be able to exploit those biomasses with lower commercial value, which currently find a scarce if not zero outlet on the market. Through the elaboration, quantities of forest biomass derived from the municipal territory defined the total production for each kind of wood for supplying the plant (in tons).

Considering a conservative average dry moisture content of 30/35% (Kruse et al., 2003; McKendry, 2002), the total biomass theoretically available is approximately 160,000 t/year in terms of dry matter.

From an economic viewpoint, the market in the Province of Rieti is affected by the distribution of the different forests. Oak coppice is always used where it has a good level of fertility and is grown on all suitable slopes. Chestnut and beech trees are used as firewood in the areas where they are most present. As far as prices are concerned, €6–8/quintal for imposed wood and €11–13/quintal for retail wood can be supposed. The imposed price, depending on the different cutting stations, is generally composed by soil cost (10–20 €/ton), cut operations (25–30 €/ton), and woodland (25–30 €/ton) for a total for 60–80 €/ton. Regarding transport processes, 10–20 €/ton can be considered in the short-brief range (some tens of kilometers), depending on the local road network. These values are all subject to variations linked to seasonal trends. However, prices have rarely reached values that could favor the valorization of the industrial energy sector in the market. At the purchase price of 50–60 €/ton, it is not conceivable to enter the firewood market. The supply of biomass power stations with assortments that could otherwise be used for the firewood market is rare; such cases have occurred under conditions of strong price contraction due to seasonal trends.

Data and assumptions of hypothetic prices of CV and energy are reported in Table 8.8, assuming a consumption of 12,000 tons of biomass. An analysis on the investment cost was carried out with an overall investment of €14 million. Average annual production is about 31,200,000 kWh, resulting into a final electric energy (EE) selling price that is the sum of the average price of Green Certification and the hypothesis price (GME) of EE (166 + 54 €/MWh).

Table 8.8. Data and assumptions of calorific value (CV) price and energy price and resulting costs and consumption. EE: electric energy; IRR: internal rate of return; NPV: net present value.

Variable	Unit	Value	Variable	Unit	Value
Installed power	MW	4	Biomass quantity per year	ton	60,000
Investment amount	€	14,000,000	Transportation cost (in 200 km)	€/ton	50
Average annual production	kWh	32,000,000	Staff cost per year	€	270,000
EE selling price	€/MWh	166 + 54	Average price Green Certification	€/MWh	166
Unit investment	€/kW	3500	Hypothesis price (GME) EE	€/MWh	54

Unit investment	€/kWh	0.45	Concessions	€	286,138
Equity	%	30	Other costs	€	390,000
Investment rate	€	1,304,000			
Financing duration	years	13			
Financing rate	%	4.01			
Discounting rate (WACC)	%	6.00			
Financed NPV	€	665,286			
IRR	%	7.01			
Pay back	year	14			

The life of the present plant is about 15 years, considering the technical life of the plant (and materials used). In an economic and financial analysis, many precautionary assumptions were adopted. A high leverage of 80% and a lease with a duration of 13 years, which is less than the incentive period, were considered. The purchase prices considered belong to the highest segment of the prices found on the market; moreover, the cost of biomass from green recovery has been set at 60 €/tons, which is higher than the real production cost.

The annual operating hours were 7800, which were lower than the operating hours of plants with similar technical characteristics. The sales values of energy and Green Certificates were 86 €/MWh and 80 €/MWh, respectively, and remained constant over 15 years; these are cautious values that are lower than the market averages of recent years. In addition, the short supply chain fuel at full capacity was set at 77% of the needs, leaving a large margin for the improvement of this model. The hypothesis is based on (i) the novelty of the supply chain mechanism and (ii) the presumed difficulty of crossing supply and demand with the local agricultural and forestry world.

Ancillary consumption reaches 18% of production, since only 83% of annual production contributes to incentivized revenue, while 17% is for auto-consumption to auxiliary cover, without contributing to revenue. The resulting return on equity (in percentage terms) can be incorporated in the fundamental concept in finance of the WACC. Analyzing the results of the economic and financial accounts, the investment exhibited positive profitability rates above the banks' lending rate of 6.5%. The NPV is reduced to zero in about six years, until reaching a value of approximately €665,286 at the end of the 15th year. The IRR is of 7.01%, while the payback period is 14 years. The total return is approximately 19%: plants with higher outputs would entail investments that could not be taken up by the increased electric efficiency. An economic and financial examination revealed the real feasibility of the plant, envisaging a return on investment of 8%. Biomass quantity per year was assumed to 60,000,000 tons. 50 €/ton is the cost, of which 10 are related to transport costs, if the supply range is a maximum of 200 km. Other operating costs (e.g., maintenance, oil, water, insurance, etc.) are estimated at €390,000.

Therefore, the construction of the plant proposed is concrete and profitable from an economic and financial standpoint. Furthermore, the core business has an EBITDA (earnings before interest, taxes, depreciation, and amortization) of over 30% (Figure 8.11). A comparable trend was also observed for the debt service coverage ratio (DSCR). The payback period embodies 14 years required to offset the investment.

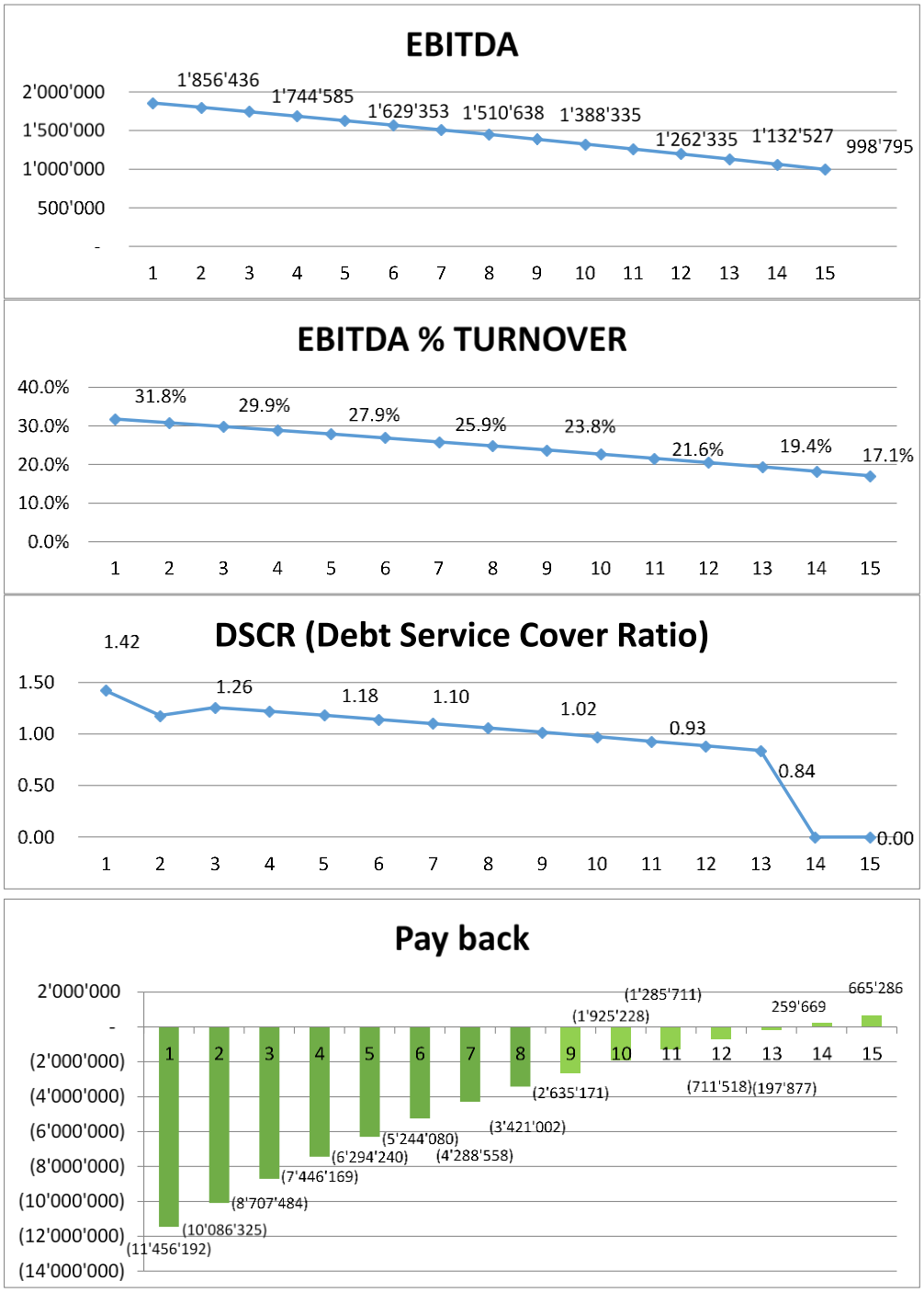


Figure 8.11. Results for earnings before interest, taxes, depreciation and amortization (EBITDA), its turnover, debt service coverage ratio (DSCR), and payback.

The staff costs are €270,000. The plant will be operated continuously (24 h in three 8-h periods). By law, the boiler requires a licensed operator on a rotating basis; three specialized workers are needed, and considering holidays and illnesses, a total of five licensed workers are needed to operate the boiler. Biomass handling and minor maintenance is carried out by a non-specialist operator per shift. This serves a total of five non-specialist operators. A standard business cost per operator of €30,000 per year was assumed. An administrative role is envisaged for the ordinary management of the business, handling incoming and outgoing invoices, whose annual cost is €40,000. The plant will be chaired by a chief manager, e.g., an engineer with experience in the sector, at a cost of €80,000 per year. Ordinary and extraordinary

maintenance will be entrusted to the same supplier firms through specific contracts that regulate the list of repetitive interventions and their timing, and the methods of intervention in the event of extraordinary maintenance.

8.3.6. Reflecting on supply chain energy chance

Using renewable sources in the energy sector requires agreeing to meet the energetic demand while respecting the environment (Talavera et al., 2015; Salerno et al., 2017). Agroenergy districts characterize a tangible chance for central realities in Italy toward sustainability and higher environmental quality, with the purpose of strengthening local socio-economic structures using new technologies (Zambon et al., 2016a). Biomass utilization can support rural development (FAO, 2000.). The degree of sustainability of the agroenergy supply chains must be evaluated, as well as their networks of production processes (Albino et al., 2007).

Based on these premises, the present work focused on a forest biomass plant that represents a complex activity that involves territorial planning, logistic activity, suitable management of the energy production plant, and a vast commercial achievement dedicated to the purchase of energy fuel. The proposed model exposed that the tangible feasibility of the plant is linked to the ability to find fuel in the neighboring area (province of Rieti, Central Italy). Generally, the plant's profit can be active only in case of the purchase of fuel in the short supply chain (Pantaleo et al., 2014; Begum et al., 2013). In the present case, the results revealed that the studied plant can be sustainable over time, owing to the relevant incidence of forest biomass in the province of Rieti, which emerged thanks to territorial analysis. The transportation costs that resulted were not so excessive due to the closeness of the location of the proposed plant to biomass source regions. The energy plant considered can benefit from different waste material, e.g., poplar cultivation (143 tons), beech trees (143 tons), deciduous trees (excluding poplar and chestnut trees) (53 tons), and castanets (884 tons). In this way, it also allows the energy plant to continuously operate, also ensuring that its operators (initially about seven people, including five operators, an administrative person, and a chief engineer with experience in the bioenergy sector) work to endlessly strengthen the employment conditions in the agricultural sector (Boubaker et al., 2014; Marucci et al., 2013; Colantoni et al., 2013).

Electric power is produced through a Rankine cycle using water as working fluid (Lecompte et al., 2015). The choice is driven by the assumption that this is a cost-effective and reliable technology, which has reached quite a mature industrial level (Amirante et al., 2015; Ellabban et al., 2014). Indeed, the fuel procurement process is the driving factor for the establishment of the plant, since it is the real and actual innovating factor of the whole process (Pantaleo et al., 2014). Considering less consolidated energy-producing technologies, e.g., pyrolysis or gasification, would highly increase the risk of a lack of cost-effectiveness for the model, making it impracticable (Begum et al., 2013; Prakash and Karunanithi, 2009).

The threshold of 10 MW (or 50 MW thermal) signifies a limit line between suppliers, mainly boiler groups and accessories. The cost of the boiler is about 50% of the total cost of the installation; consequently, its impact on the return on investment is significant. The domestic market for suppliers of boilers below 50 MW is fragmented, consisting of a few firms that offer steam generation systems from other industrial sectors, e.g., steam generation for processes powered by cellulosic non-wood fuels. Above the threshold of 50 thermal MW, large national and international firms have an extensive experience in boilers, supporting the energy production of electricity. Many of them also act as general contractors, since the boiler is the most essential component of this energy system. Furthermore, the market for large boilers is unquestionably more structured and competitive, allowing costs that are less linked to the different product sectors for which the boilers are used (Galik and Abt, 2016; Giacomarra and Bono, 2015). The model of the present work requires that energy fuel must be supplied to the neighboring territory as territorial capacity involves the installable power (Zambon et al., 2017a; Garofalo et al., 2015; San Miguel

et al., 2015; Giuffrida and Gagliano, 2015). The focus was on drawing up the biomass supply plan, which is strictly linked to the local territory. The fluctuating market trend affecting the entire agricultural sector requires planning activity (Barnes et al., 2015; Borodin et al., 2016). Therefore, the energy potential of the investigated territory, the province, and the municipality of Rieti can be considered an interesting case study.

Environmentally, the impact of the proposed plant was measured exclusively on atmospheric emissions, as the plant is placed in industrial areas without landscape or naturalistic value (Colantoni et al., 2015a, c). The emissions levels of the plant are well below those required by law (the Legislative Decree of March 2006 sets out provisions concerning biomass combustion plants and the relative atmospheric emissions), representing a further positive element for obtaining the production authorization. Generally, the laws on renewable energy reward these kinds of plants; they provide energy efficiency rewards. From the environmental point of view, the plant is fully consistent with local and national laws, since emissions that concern the present plant are largely under legal thresholds thanks to the use of forest biomass as energy fuel, the enhanced combustion capacity of modern boilers, and the gas treatment that it envisages.

From an economic and financial viewpoint, an analysis of the investment cost was carried out with an overall investment of €14 million. The NPV is reduced to zero in about six years, until reaching a value of approximately €5 million at the end of the 15th year. The total return is approximately 19%: plants with higher outputs would entail investments that could not be taken up by the increased electric efficiency. An economic and financial examination to find out the real feasibility of the plant was carried out, envisaging a return on investment of 8%.

Regarding the purchase costs of the different types of biomass, prices appeared to be relatively stable. Boiler mouth biomass prices are the sum of several items, e.g., the raw material, its collection, cutting, chipping, transport, and storage. The latter stages are generally carried out by different actors. Speculative mechanisms are much more difficult in this context, since forest biomass has margins for cost reduction, as it practically represents an innovative market in Rieti's province.

The production of energy from vegetable biomass compared with production from other renewable sources, e.g., wind or hydroelectric sources, appears less profitable, but has an environmental impact that is generated exclusively by emissions, and a certainly higher employment impact, because it creates an induced link to the activities of biomass supply. A direct combustion biomass plant compared with a wind or hydroelectric plant with equal production capacity has an energy generation cost that is higher than 40% to 100% (Lorenzoni et al., 2007). There are seven direct employment places that generate the biomass power plant under study, whose products are economic-induced and can be estimated as equal to the purchase value of biomass in the short supply chain. For the plant in question, this is equal to €2,500,000 annually for 15 years. The direct employment of a plant with the same wind or hydroelectric production capacity can be estimated at two units; meanwhile, the supply chain is almost zero.

Energy costs from forest biomass are therefore certainly higher (Paolotti et al., 2017; Gravelsins et al., 2017; Fagarazzi et al., 2014; Young et al., 2018). However, the plant also represents a vital opportunity (Carlucci et al., 2015; Sgroi et al., 2018) for the territory of Rieti. It should also be noted that the supply chain supports the agricultural and forestry sector, which currently are in a structural crisis (Zambon et al., 2018; Secco et al., 2017) in central Italy. The employment effect plays a significant role in the concession process due to the interaction among renewable energy production and agriculture (Zambon et al., 2016b, 2018; Manos et al., 2014). Although the biomass power plant is less competitive than other renewable energy sources from a profit and loss point of view (e.g., solar plants), the greater ease of the concession process and the close interaction with the agricultural and forestry business environments are key strengths (Petrescu et al., 2017; Ullah et al., 2015).

8.4. Costs-benefits analysis and electric energy production

The production of electrical energy from the bio energy sector revealed an average increase of 19% a year in Italy in recent years (between 2001 and 2014) from 1,958 to 18,732 GWh (GSE, 2014). In 2014, it accounted for 15.5% of total production from renewable sources. The increase in the energy production from biogas was relevant: it rose from 1,665 GWh in 2009 up to 8,198 GWh in 2014 (GSE, 2014). In this setting, the biggest increase concerned biogas plants using manure derived from animals (Tricase and Lombardi, 2009; Schievano et al., 2009).

The business decision in respect of the construction of an anaerobic digestion plant in a farm almost always involves expensive investments (Piccinini et al., 2008; Agostini et al., 2016). Even in smaller firms, significant investment costs cannot be addressed without having a clear framework of their profitability and changes that such technology determines in a productive and managerial identity (Salomon and Lora, 2009; Delzeit and Kellner, 2013). Besides the technical aspects, the entrepreneur should be able to assess the sensitivity of the investment profitability (e.g. Patrizio and Chinese, 2016) to changes in active items, such as electricity, price of incentives and incidence of public contributions (Piccinini et al., 2008). In order that a farmer can obtain economic benefits enough to repay both his own work and investment, considering the payback time (Holm-Nielsen et al., 2009; Karellas et al., 2010; Carlini et al., 2014), the entrepreneurial choice should be approached with a deep cost-benefit analysis that the introduction of anaerobic digestion technology involves (Piccinini et al., 2008; Uellendahl et al., 2008).

Cited article

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8.4.1. A small-scale biogas plant in the Italian rurality

A representative biogas plant of small size (250 kWel) in the Italian context is in a farm. The bio-matrix produced, as feedstock for the biogas plant, is classifiable as a biological origin by-product consists of a daily sewage volume coming from pig breeding estimated in 31 tons a day, with the corn contribution of about 9 tons a day.

The contribution of corn in the total bio-matrix input is therefore less than 30%, allowing to fall into the type of organic by-products. In addition, since the plant power is less than 300 kWel, the incentive rate is the maximum available: it was of € 0.236/kWhel, as stated in the Tab.1.1 of the Attachment 1 in Italian Ministerial Decree n. 28 of 6/7/2012; while it became of € 0.233/kWhel, as reported in Tab. 1.1 of Appendix 1 of the Italian Ministerial Decree of 23/6/2016. Regarding the study concerning the use of a bio-matrix classifiable as a product of biological origin, a percentage in corn weight of 37.5% was considered. The use of bio-matrix reduced the value of the incentive rate: it was € 0.180/kWhel regarding the Italian Ministerial Decree n. 28 of 6/7/2012; while it became of € 0.170/kWhel referring to Italian Ministerial Decree of 23/6/2016.

In the case of the old all-inclusive rate, the incentive corresponds to € 0.280/kWhel apart from the fact that the bio-matrix is classifiable as a product or by-product. The database for the calculation of the B.M.P. index (Biochemical Methane Potential) was used for the cost-benefit analysis (Koupaieet al., 2014; Esposito et al., 2012). In the study context, from the economic point of view, it is hypothesized the use of financial indebtedness for 100% of the investment. The characteristics of a representative plant with particular reference to the engine to energy electric production are reported in Table 8.9. The specific costs derived from the subsidized plant monitoring activity are summarized in Table 8.10. The estimation carried out for the construction of a small biogas plant of 250 kWel, fed with the considered matrix, identified the main costs for its construction and maintenance (Table 8.11 and 8.12).

Table 8.9. Characteristics of a representative plant.

Parameter	Unit of measurement	All-inclusive rate	Italian Ministerial Decree n. 28/2012	Italian Ministerial Decree June 23th, 2016
Plant functioning	(day/ year)	365	365	365
Process temperature	(°C)	35	35	35
Low Heat Value CH4	(kWh/Nm^3)	9.88	9.88	9.88
Methane percentage	(%)	60	60	60
Cogenerator working hours	(h/year)	8200	8200	8200
Cogenerator total power	(kW)	713	713	713
Electrical performance	(%)	35%	35%	35%
Thermal performance	(%)	40%	40%	40%
Cogenerator electrical power	(kW)	250,00	250,00	250,00
Gross electrical energy produced	(kWhel)	2,050,000	2,050,000	2,050,000
Gross thermal energy produced	(kWh)	3,807,143	3,807,143	3,807,143
Self-use electric energy (EE)	(%)	7	11	11
Net electrical energy produced	(kWhel)	1,906,500	1,824,500	1,824,500

Table 8.10. Specific costs.

Parameter	Unit of measurement	Value
Service cost (including maintenance)	(€/kWh)	0.025
Anaerobic Digestion Plant specific cost	(€/m3)	200
Cogenerator specific cost	(€/kWel)	1.500
Additional storage tank	(€/m3)	50
Biomass storage silos	(€/t)	50
Silage	(€/t)	40

Table 8.11. The estimated investment for the construction of the biogas plant considered in the study.

Device	Cost (€)
Anaerobic Digestion Plant	429,821
Cogenerator	375,000
Tank for Silage	182,500
Grid connection of medium voltage	60,000
Planning and Safety Costs	37,000
Various Costs	80,000
TOTAL	1,164,321

Table 8.12. Management and plant maintenance costs.

Resource	By-product case (€/year)	Product case (€/year)
Full Service (maintenance included)	51,250	51,250
Organic matrices	146,000	160,600
Insurance policy	3,000	3,000
Biology monitoring	15,000	15,000
Digestate scattering	5,000	5,000
TOTAL	220,250	234,850

In the specific case related to the use of by-products and products such bio-matrices in input to the plant has been studied with respect to three kinds of incentive systems or the all-inclusive rate, to Italian Ministerial Decree n. 28/2012 and Italian Ministerial Decree of 23/6/2016.

Economic and financial characteristics of the investment are illustrated when the plant is subsidized under the old all-inclusive rate. Above all, the NPV index (net present value) represents the difference between the sum of all the discounted cash flow (gross operating margins of 15 years discounted at year 0), and the investment appears positive and equal to € 1,881,148 (Figure 8.12). This result means that the

investment is economically and financially profitable as it creates value.

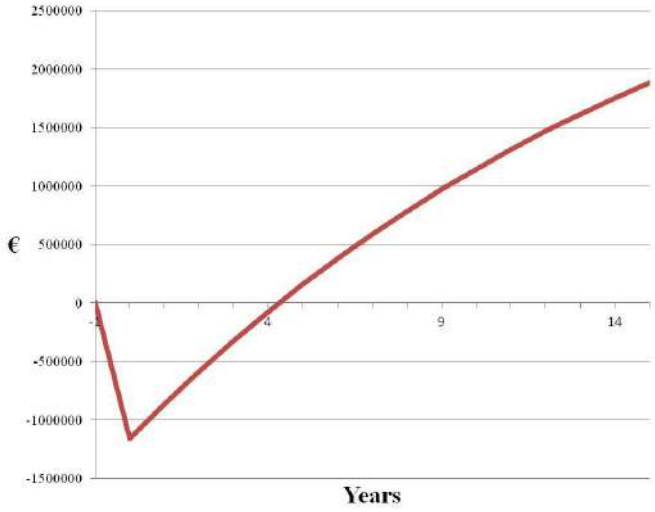


Figure 8.12. NPV tendency - All-inclusive rate.

Another alternative method of investment valuing closely related to NPV is IRR (Internal Rate of Return) that is used to evaluate the attractiveness of a project or investment. It represents the interest rate at which the NPV of all the cash flows (both positive and negative) from a project or investment is equal zero. The investment project is desirable because the IRR, the value of which is equal to 26.1%, is higher than the capital opportunity cost, assumed 6% for comparable risk projects. It is characterized by a Pay-back Time (PBT) of less than 4 years (Table 8.13).

Table 8.13. Economic analysis.

Parameter	All-inclusive rate1	Italian Ministerial Decree n. 28/2012	
		by-product	product
Incentive duration*	15	20	20
Rate **	0.28	0.236	0.180
Sale Earning EE ***	533,820	430,582	328,410
Investment ****	1,164,321	1,164,321	1,164,321
Gross operative margin ***	313,570	210,332	108,160
Pay Back Time*	3.7	5.5	10.8
Share capital ***	77,621	58,216	58,216
Net operative margin ***	235,948	152,115	49,943
Passive interests ***	42,260	43,294	43,294
Total interests ****	633,904	865,895	865,895
Initial Finance ****	1,798,226	2,030,216	2,030,216
Net income ***	193,688	108,821	6,649
Interest rate (%)	6.00%	6.00%	6.00%
NPV ****	1,881,148	1,248,170	76,265
IRR (%)	26.1%	17.3%	6.8%

Parameter	All-inclusive rate2	Italian Ministerial Decree (June 2016)	
		by-product	product
Incentive duration*	15	20	20
Rate **	0.28	0.233	0.170
Sale Earning EE ***	533,820	425,109	310,165
Investment ****	1,164,321	1,164,321	1,164,321
Gross operative margin ***	313,570	204,859	75,315
Pay Back Time*	3.7	5.7	15.5
Share capital ***	77,621	58,216	58,216
Net operative margin ***	235,948	146,642	17,098
Passive interests ***	42,260	43,294	43,294

[1] It should be noted that according to the incentive system based on all-inclusive rate there is no distinction of bio-matrix in product or by-product.
[2] It should be noted that according to the incentive system based on all-inclusive rate there is no distinction of bio-matrix in product or by-product.

Total interests ****	633,904	865,895	865,895
Initial Finance ****	1,798,226	2,030,216	2,030,216
Net income ***	193,688	103,347	-26,195
Interest rate (%)	6.00%	6.00%	6.00%
NPV ****	1,881,148	1,185,389	-300,464
IRR (%)	26.1%	16.8%	2.6%

* in years

** in € / kWh

*** in € / year

**** in €

The same system seen before has also been studied in relation to the incentive system associated with the proposed tariffs in Italian Ministerial Decree n. 28/2012 and Italian Ministerial Decree on June 23th, 2016, where by-products and products are used as inputs (such as bio-matrices).

Since the plant remains the same, both the investment and management costs are unchanged. However, the amount of the incentive rate appears different: in the case of use of by-products, it is equal to € 236/MWhel according to Italian Ministerial Decree n. 28/2012, and € 233/MWhel according to Italian Ministerial Decree on June 23th, 2016. If the bio-matrix is classified as product, the incentive would be reduced to € 180/MWhel and € 170/MWhel. When calculating the profitability of the plant using the aforementioned two decrees, it is crucial to think about, with respect to the old all-inclusive rate, an incentive time horizon that increase from 15 to 20 years, in addition to a self-consumption of less than 11%. Any difference would be counted and paid by the Italian Manager of Energy Services (GSE) at the market price, which is about € 100/MWhel. Though, such aspect was not considered in the present work. Similarly, the H.E.C. bonus (High-efficiency cogeneration) was not considered, as nitrogen bonus and other expected rewards: their valuation is difficult to estimate and therefore they do not correspond to a definite income. It should be emphasized that the non-consideration of the above bonuses and rewards is adopted by all the plant companies which build plants in drafting the investment business plan.

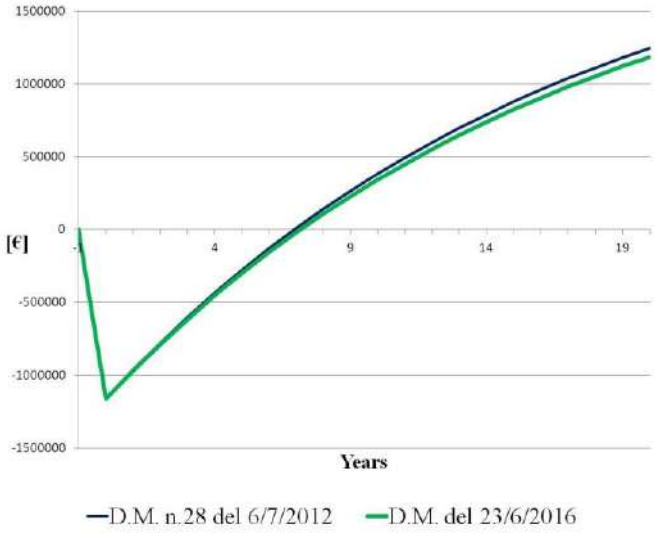


Figure 8.13. NPV tendency – proposed fares in the Italian Ministerial Decree n. 28/2012 and Italian Ministerial Decree on June 23th, 2016 in the case of by-product use and of product.

From the analysis above, results proved how the values of NPV, IRR and PBT (Profit Before Tax) highlight that an investment of this type appears to be financially risky. This statement is mainly since the incentive value drastically is reduced from € 280/ MWhel of the all-inclusive rate to 180 €/MWhel of Italian Ministerial Decree n. 28/2012 and 170 €/MWhel in the case of Italian Ministerial Decree on June 23th, 2016. Furthermore, the rising costs of bio-matrix, due to the increase led by the amount present in the composition of the same bio-matrix, should be considered.

Finally, alternative energy sources are becoming ever more a global reality: their use allow both to meet the growing demand for energy and to reduce the environmental impact (Monarca et al., 2011). From the economic and financial analysis and the comparative study, results revealed how the biogas plants from 250 kWel are still an attractive investment (Karellas et al., 2010), despite the obvious reduction the incentive base rate has suffered over the years (Agostini et al., 2016). From how the current incentive legislation is structured, small plants (with a power less than 300 kWel) have the best incentive rate. Particularly, these plants are convenient only if the biomass used is: (i) classifiable as a "by-product of biological origin"; or if (ii) it is constituted for at least 70% in weight by by-products, which normally represents a zero-cost biomass. Livestock production involves a significant environmental damage (Mathias, 2014). An additional advantage in the biogas production derives from the fact that it avoids environmental problems, also due to the spreading of manure directly in soil and other issues concerning the sewage disposal (Tricase and Lombardi, 2009; Hoppe et al., 2016). In this background, a biogas plant provides (i) an economic return in relation to the sale of produced EE (Electric energy) and at the same time (ii) avoids the trouble of disposing of the slurry and their related costs. Besides, the digestate (a by-product of the anaerobic digestion process) can be used as fertilizer for the major agricultural crops, in full or partial replacement of chemical fertilizers on the market, thereby reducing the farming management costs. So, small biogas production plants enable positive benefits in social, economic and environmental terms. Actually, small plants fed with by-products or agro-industrial waste allow: (i) the recovery and the reuse of production waste; (ii) the possible enhancement of a short chain; and (iii) a sustainable development, as well at the local scale (e.g. Bond and Templeton, 2011).

8.5. Solar plants among environmental degradation and complex backgrounds

Since photovoltaic (PV) energy contributes to reduce pollutant emissions, the spread of solar energy plants has been widely supported as a response to global climate change (Bergesen et al., 2014) in regions with optimal conditions for photovoltaic fields due to a large and continuous solar irradiation along the year (Espinosa et al., 2014; Gunderson et al., 2015). Incorporating solar plants on existing grazing or agricultural land provides an additional income stream to land owners and promotes diversification of revenue for years when agricultural productivity is low or for crops that are relatively low value. Similar benefits have been demonstrated with wind developments on agricultural lands (Holmes and Papay, 2011). Based on these premises, ground-mounted photovoltaic fields are becoming a common infrastructure in the Mediterranean region and may contribute, at least indirectly, to various forms of environmental degradation including landscape deterioration, land take, soil degradation and loss in traditional cropland and biodiversity. While energy, economic and environmental impacts of photovoltaic plants have been generally seen as positive, the large-scale use has a negative impact on rural landscapes (Carullo et al., 2013; Naspetti et al., 2016). Specific impacts on soils and rural communities (e.g. in terms of permanent or temporary soil sealing, total or partial soil shading, degradation of land, habitat fragmentation and loss of traditional agricultural practices) have been identified and require further investigation (Beylot et al., 2014; Hernandez et al., 2014a; Koldrack et al., 2014).

Cited article

Delfanti, L.M.P., Colantoni, A., Recanatesi, F., Bencardino, M., Sateriano, A., Zambon, I., Salvati, L. (2016). Solar Plants, Environmental Degradation And Local Socioeconomic Contexts: A Case Study In A Mediterranean Country. Environmental Impact Assessment Review 61, 88-93.

Solar power installations can be either temporary or permanent and can be mounted at a variable distance from the ground, causing a variable impact on soils and on the overall land quality. Crops that are shade tolerant and low height may become suitable for production in an area with photovoltaic fields (Harinarayana and Sri Venkata Vasavi, 2014). At the same time, shade from solar infrastructure generally reduces crop productivity. Moreover, agricultural activities involving large machinery may have limited options for co-location with solar infrastructure (Beckman and Xiarchos, 2013). Soil shading by extensive photovoltaic fields can also reduce its infiltration capacity, altering the surface hydrological balance and determining, in some cases, an increased runoff possibly enhancing soil erosion processes. Previous studies have proposed strategies to reduce the environmental impact of photovoltaic fields (e.g. Graebig et al., 2010), indicating some possible solutions including a more complete integration into buildings and infrastructures - keeping ground-mounted installations to a minimum (Holmes and Papay, 2011). It has been also proposed to restrict the installation of ground-mounted systems on low-quality land, including brownfield sites or in the close vicinity of highways and railway lines (Beck et al., 2012). In both cases, spatially-detailed diachronic information on the expansion of solar plants into rural areas is required to support fine-tuned strategies aimed at reducing the environmental impacts of photovoltaic plants.

However, local-scale information on the spatial distribution of ground-mounted photovoltaic fields and their possible impact on rural landscapes are generally scarce, fragmented or poorly comparable among regions or countries. Occupied surfaces are one of the critical variables regarding the environmental performances of large-scale ground-mounted photovoltaic installations. The occupied surface mainly determines the impact of large-scale installations on land quality (Costantini and Lorenzetti, 2013).

8.5.1. PV expansion in Italy

A rapid expansion in solar generation capacity has been recorded in Europe since 2005: solar-based electricity generation increased more than 10 times over the period 2005-2010 (Eurostat, 2012). According the recent report "Energy, transport and environment indicators" elaborated by Eurostat, the gross inland

consumption deriving from solar photovoltaic source in the 28 European Union countries increased from 126 to 7939 thousand TOE (tonnes of oil equivalent) between 2005 and 2014. In 2012, Italy was the second country in the world for installed capacity of photovoltaic plants (INEA, 2013). Photovoltaic plants have developed recently in Italian rural areas, becoming highly attractive due to high earnings compared to traditional agriculture (Marcheggiani et al., 2013). An increased surface area of high-quality cropland was converted to solar power plants in the last decade (GSE, 2012). This phenomenon has progressively led to a significant reduction of the utilized agricultural area in some rural districts with traditional agro-forest environments, possibly determining loss in food production and the consequent alteration of the landscape value (Costantini and Lorenzetti, 2013; Kim et al., 2013; Tani et al., 2014).

A debate on the environmental impact of photovoltaic fields in terms of land occupation has progressively involved the public opinion in the very last years. Chiabrando et al. (2009) have tried to clarify the territorial impacts of the ground-mounted photovoltaic systems in Italy. Agricultural areas, destined to ground-mounted photovoltaic plants, have been estimated at 134 km^2, corresponding to 0.1% of Italian agricultural surface area (Squatrito et al., 2014). National institutions have recently placed some limits to the uncontrolled development of ground-mounted photovoltaic plants on rural land. National incentives granted to photovoltaic systems installed on agricultural land have been removed. The Italian Ministry of the Environment has proposed initiatives to manage and plan the installation of photovoltaic fields on rural land and to contain landscape and soil degradation, land take and loss of traditional cropland (INEA, 2013). A substantial reduction in the price for energy has been also observed in the last years; therefore, market has experienced a setback of new installations from over 1 GW in 2013 to about 385 MW in 2014, below the estimates of the beginning of 2014 (GSE, 2012).

Effective and reliable indicators based on the spatial distribution of solar plants are required to assess the environmental vulnerability of different local contexts to the expansion of ground-mounted photovoltaic fields (Schiffer, 2015). An indicator-based approach was proposed that assesses the expansion of photovoltaic plants installed on rural land in Italy, identifying at the same time the socioeconomic context of local communities experiencing various levels of photovoltaic plant density. Rural contexts were described considering topography, land-use and demography indicators. The approach can be extended to other European countries, being possibly integrated in a comprehensive strategy harmonizing sustainable development and landscape conservation of traditional agricultural areas.

8.5.2. PV expansion *vs* land degradation processes

Elementary data of photovoltaic plants installed in Italy between January 2005 and December 2014 were derived from the Atlasole database provided by the Italian Energy Services Manager (GSE) by municipality and plant power. For each administrative region of Italy, the surface area of rural land occupied by photovoltaic fields was provided by GSE (2012). Plants were classified by installation support (e.g. ground, building or greenhouse roof, infrastructures). The total surface area of photovoltaic fields (m^2) was provided separately for each region, together with the number of plants and their total power (MW). The percentage of ground-mounted plants in the total number of installed photovoltaic plants was finally reported. On average, ground-mounted plants in Italy covered a surface area of 1.7 hectares per MW (GSE, 2012). Additional data referring to 2011 were derived from official statistics provided by ISTAT (Italian National Statistics Institute) including average elevation, total surface area and population density for each Italian municipality.

For each Italian municipality, the surface area of land occupied by ground-mounted photovoltaic plants was estimated for two points in time (2007 and 2014) by disaggregating the total surface area covered by ground-mounted photovoltaic fields at the regional scale. Since the surface area of land destined to photovoltaic fields in each Italian administrative region corresponds to the total surface area covered by

photovoltaic fields in all municipalities of that region, the municipal surface area of ground-mounted photovoltaic fields (unknown) - depending on the number and power of installations in each municipality (known) - was estimated as proportional to the total number and power of installations recorded in each administrative region (known). The amount of the total surface area occupied by ground-mounted photovoltaic fields in each Italian municipality was estimated for 2007 and 2014 (Hernandez et al., 2014b). For each Italian municipality, five contextual indicators were calculated: (i) average elevation (m), (ii) population density for 2007 (inhabitants/km^2), (iii) percent change in population density between 2007 and 2014, (iv) total surface area administered by each municipality (km^2) and (v) a binary (0-1) variable distinguishing southern Italy municipalities (1) from central and northern Italy municipalities (0).

Table 8.14 reports selected indicators estimating land destined to ground-mounted photovoltaic fields in Italy by year, geographical division, elevation and class of population density. The percent area covered by photovoltaic fields in the total country area was estimated at 0.03% in 2007 and increased to 0.06% in 2014. After a major spread of ground-mounted photovoltaic fields in southern Italy up to 2007 (Figure 8.14), the largest increase in the number of photovoltaic plants was observed in rural areas of central Italy over 2007-2014 (0.07%). In this region, the percent land area covered by photovoltaic fields in the total surface area was 0.09% in 2014. This figure is moderately higher in respect to what was observed in southern Italy (0.08%) and substantially higher than the value observed in northern Italy (0.02%).

Table 8.14. Estimated sealed land by photovoltaic plants in Italy by year, geographical division, elevation and population density class.

Variable	Class area (%)			Share in the total sealed area (%)		
	2007	2014	% change	2007	2014	% change
Geographical division						
North	0.007	0.024	0.017	9.0	15.4	6.4
Centre	0.019	0.091	0.073	12.3	28.8	16.5
South	0.056	0.083	0.027	78.7	55.8	-22.9
Elevation (m)						
< 100	0.065	0.120	0.055	29.4	26.1	-3.4
100 - 300	0.062	0.132	0.071	40.6	41.5	0.9
300 - 500	0.030	0.058	0.028	19.4	18.1	-1.3
500 - 800	0.012	0.030	0.018	8.1	9.6	1.4
> 800	0.002	0.010	0.008	2.4	4.7	2.4
Population density (inhabitants/km^2)						
< 100	0.010	0.024	0.014	20.3	22.7	2.4
100 - 300	0.063	0.107	0.043	57.9	46.5	-11.4
300 - 500	0.036	0.103	0.067	8.6	11.7	3.1
> 500	0.049	0.147	0.098	13.2	19.1	5.9

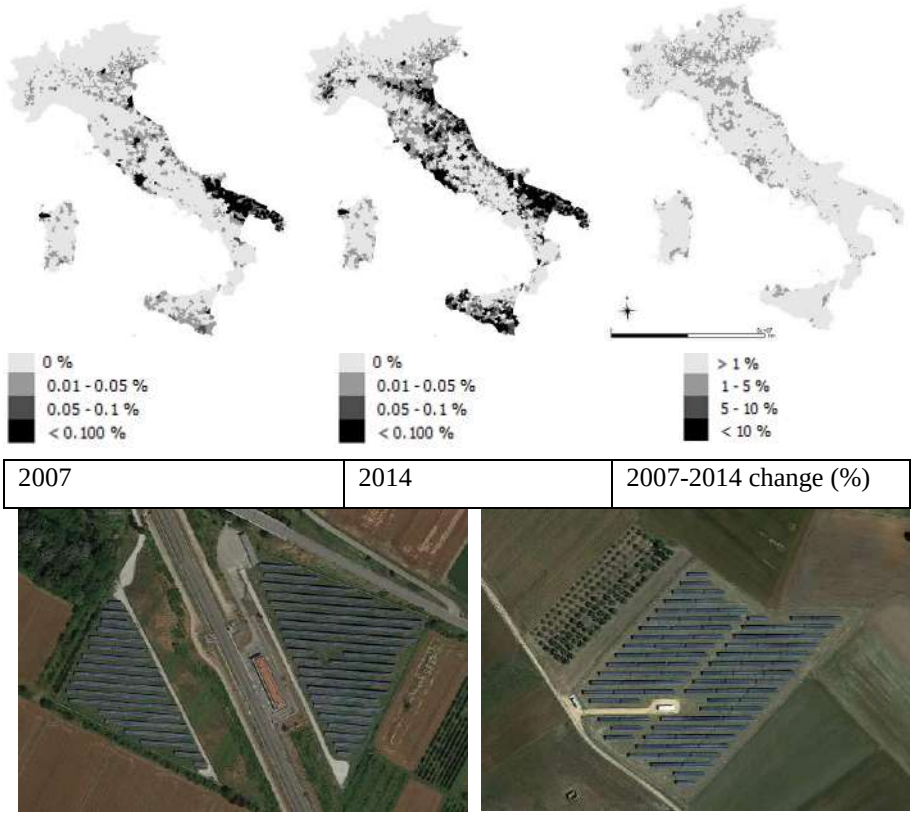


Figure 8.14. Spatial distribution of land sealed by photovoltaic plants in Italy by year (upper panel) and two aerial views of photovoltaic fields (lower panel) in a flat area (northern Italy, left) and in a steep area (central Italy, right), courtesy of Google Earth.

The concentration of photovoltaic fields in central and southern Italy mainly depends on the optimal environmental conditions found in those areas, namely the higher solar radiation compared with northern Italy. However, important changes in the geography of photovoltaic fields in Italy have been observed between 2007 and 2014. Southern Italy concentrated more than 78% of ground photovoltaic surface area in 2007 shifting to 56% in 2014; at that time, central and northern Italy concentrated respectively 15% and 29% of the total ground photovoltaic surface area in Italy.

Photovoltaic fields were mainly located on flat or moderately steep rural land with elevation < 300 m. The 0-300 m elevation zone concentrated the largest increase in the surface area covered by ground-mounted photovoltaic fields between 2007 and 2014. The highest concentration of photovoltaic fields was observed in rural municipalities with intermediate population density (100 - 300 inhabitants/km^2). The surface area covered by ground-mounted photovoltaic fields in 2007 increased in southern Italy municipalities ($r_s = 0.21$, $p < 0.05$, $n = 8092$) and in municipalities administering large surface areas ($r_s = 0.17$, $p < 0.05$, $n = 8092$). In 2014, the surface area covered by ground-mounted photovoltaic fields increased with the size of municipalities ($r_s = 0.29$, $p < 0.05$, $n = 8092$) and decreased with elevation ($r_s = -0.15$, $p < 0.05$, $n = 8092$).

Results of a Principal Component Analysis carried out 7 contextual variables including the estimated area of ground-mounted photovoltaic fields for each Italian municipality in both 2007 and 2014. The PCA extracted three components explaining respectively 29%, 28% and 15% of the total data variance. Component 1 identified a gradient opposing densely populated areas (with growing population) to economically-marginal and mountainous districts. Component 1 was not correlated with the percentage of sealed land in both 2007 and 2014. Component 2 was associated negatively to elevation and positively to population density and the percent area of land covered by photovoltaic fields in both 2007 and 2014.

Component 3 illustrated the latitude gradient from northern Italy to southern Italy and was not correlated with the percent area of land covered by photovoltaic plants. Figure 8.15 reports a PCA biplot discriminating municipalities with the highest estimated surface area of ground-mounted photovoltaic fields (ordered along the 'Sea' variable axis). These municipalities are concentrated primarily in southern Italy and in flat areas of central and northern Italy.

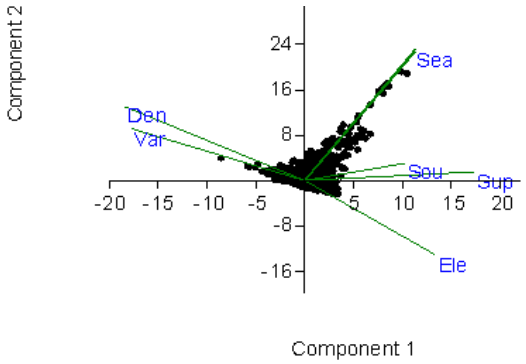


Figure 8.15. Principal Component Analysis biplot (Sea = percent sealed land in 2007 and 2014, Den = population density (2007), Var = population growth rate (2007-2014), Ele = elevation, Sup = municipal surface area, Sou = binary variable indicating southern Italy municipalities).

Non-hierarchical clustering identified four homogeneous groups of municipalities with distinct socioeconomic characteristics. Clusters were ordered according to the percent surface area of photovoltaic fields in the municipal surface area (2007). In 2007, the highest percent class area was observed in municipalities belonging to cluster 4 and concentrated in moderately steep areas of southern and central Italy with relatively low population density (148 inhabitants/km^2 on average) (Figure 8.16). However, the largest expansion of ground-mounted photovoltaic fields was observed in dense municipalities (465 inhabitants/km^2 on average) administering flat areas of both central and northern Italy (cluster 3).

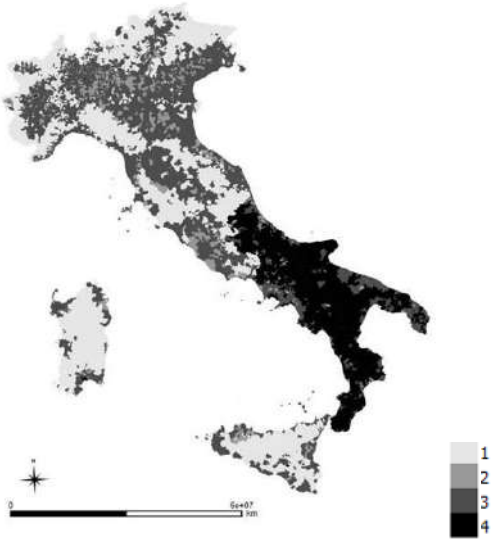


Figure 8.16. Classification of Italian municipalities into homogeneous k-means clusters.

8.5.3. PV implications in sustainable local developments

Solar energy plants have risen exponentially and globally (Booth, 2014; Hernandez et al., 2014a, 2014b; Jäger-Waldau et al., 2011). Photovoltaic technology has had a significant success in the energy market (Gunderson et al., 2015; Suri et al., 2007). According to Dupraz et al. (2011), integrating new sources of renewable energy with crop production is a feasible solution provided that a high rate of soil sealing is prevented. However, legislation often failed to assess the negative impact of photovoltaic fields altering

soil, landscape and cropping systems (Kapetanakis et al., 2014; Marcheggiani et al., 2013; Vasseur and Kemp, 2011). Since the development of photovoltaic systems has led to a considerable loss of farmland (Stephens and Angel, 2012), effective management strategies and appropriate policies are required to preserve southern European rural land from environmental degradation possibly caused by the unplanned installation of ground-mounted photovoltaic fields or other temporary or permanent structures, such as greenhouses (Marrou et al., 2013; Nonhebel, 2005; Tsantopoulos et al., 2014). Information on topography, land-use, demography and, more generally, a set of socioeconomic indicators profiling the local context, should be considered in the decision-making process to minimize the environmental impact of photovoltaic plants in terms of landscape and soil degradation, land take and loss in traditional agricultural practices (Guerrero-Lemus et al., 2015; Holtmeyer et al., 2013; Murphy et al., 2015; Talavera et al., 2014).

The approach proposed estimates the amount of rural land covered by photovoltaic fields at a disaggregated spatial scale in Italy. According to Fabiani and Tartaglia (2013), the evolution of photovoltaic systems in Italy started with the great race of energy giants, stimulated by substantial gains guaranteed by photovoltaic fields. Large agricultural land was purchased at a low cost to develop solar power plants. Between 2007 and 2014, photovoltaic fields have spread mostly in central and northern Italy, possibly due to the progressive saturation of the photovoltaic market in southern Italy. The expansion of photovoltaic fields into rural land is particularly evident in flat and moderately steep areas, with negative environmental impacts since these areas are also exposed to a higher human pressure in respect with economically-marginal and mountainous areas (Salvati and Zitti, 2009).

A progressive shift in the spatial distribution of ground-mounted photovoltaic fields in Italy was observed from less populated (and partly abandoned) rural areas characterized by economic marginality to more populated and accessible rural areas surrounding metropolitan regions. Multivariate analysis identified rural municipalities in southern Italy with intermediate population density, high transport accessibility, large availability of cropland and flat land as the most vulnerable areas to the expansion of ground-mounted photovoltaic fields.

To reduce the environmental impact of solar plants, it has been proposed to restrict the installation of ground-mounted systems on low-quality land, including brownfield sites or in the close vicinity of highways and railway lines (Beck et al., 2012). Impacts on traditional agriculture and natural habitats could be minimized by utilizing already degraded, contaminated, or marginal lands that might not sustain viable wildlife populations or be considered for agriculture production (Weinzettel et al., 2013). By contrast, the results indicate that the recent expansion of solar systems in Italy was mainly concentrated on both traditional and intensive agricultural districts in flat and hilly areas with optimal or sub-optimal conditions for cropping. The spreading of ground photovoltaic fields over accessible, medium-density rural areas, is the result of heterogeneous (and possibly poorly effective) planning measures regulating the spatial development of rural areas traditionally devoted to intensive agriculture (Ceccarelli et al., 2014).

The recent evolution of national and regional regulations in Italy is in line with the articulated territorial and socioeconomic local contexts described above. The boom of ground-mounted photovoltaic systems forced institutions, such as the Italian Ministry of Agriculture, to implement rules to contain the expansion of photovoltaic plants into greenfields (4th Energy Bill) which limited installations to 10% of the farm utilized agricultural area, prescribing also a minimum distance for installations falling on the same property. The most recent 5th Energy Bill definitely prohibited photovoltaic plant installations on greenfields. Effective planning actions have been also undertaken by some regional authorities in Italy. In 2011, Apulia (southern Italy) regional authority prepared guidelines for the sustainable management of photovoltaic fields within a spatial planning directive addressing sustainable development of rural land. Guidelines have indicated a thorough reduction of photovoltaic fields on fertile rural land allowing new

installations of plants on roofs and other built structures. Sardinia regional authority approved a landscape management plan that provides regulatory measures to the expansion of photovoltaic plants over rural areas devoted to agriculture. In the last two years, the lowest expansion of ground-mounted photovoltaic fields in the country was observed in the regions which have adopted strict regulations and a more effective spatial planning (GSE, 2012).

8.6. Combination of agricultural and energy purposes

Agricultural land loss and abandonment, excessive rate of land consumption and sealing soil represent some of the recent challenges in Europe (Benayas et al., 2007; Stoate et al., 2001; EC, 2012). For this reason, the European Union introduced policies and strategies for evolving a greater awareness towards sustainable attitudes and therefore by taking renewable energies the main role both in the primary and energy sector (Cossu et al., 2010). An example can refer to the evolution of the photovoltaic (PV) industry: the latter has rapidly spread in recent years thanks to the European energy policies but above all to favourable subsidy policies for their installation (Bürer and Wüstenhagen, 2009; Badcock and Lenzen, 2010; Szabó et al., 2010; Sgroi et al., 2014; Bigerna et al., 2017). Given their strong diffusion, PV plants constitute an element of the modern Mediterranean landscape in Europe (Delfanti et al., 2016). Many studies have focused on PV systems in Italy, as they allow substantial energy saving, rural multi-functionality and diversification of farmers' income (Tudisca et al., 2013; Marcheggiani et al., 2013) and guarantee a suitable economic perspective under the new Italian regulatory framework (Lazzeroni et al., 2016). On the other hand, the installation of ground-based PV systems has involved the use of rural land for energy purpose, resulting into an increase of soil sealing, landscape deterioration, speculative activities and other negative environmental and biodiversity effects in rural landscapes (Beylot et al., 2011; Marcheggiani et al., 2013; Harinarayana and Sri Venkata Vasavi, 2014; Taylor, 2014; Colantoni et al., 2015a, b; Delfanti et al., 2016). So, since 2013 they have been banned on agricultural soils, promoting their mounting only on existing structures, such as urban buildings (Cellura et al., 2012) or rural greenhouses (GSE, 2013; Castellano, 2014).

Cited article

Marucci, A., Zambon, I., Colantoni, A., Monarca, D. (2018). A Combination Of Agricultural And Energy Purposes: Evaluation Of A Prototype Of Photovoltaic Greenhouse Tunnel. Renewable And Sustainable Energy Reviews 82, 1178-1186.

Based on these premises and combining agricultural and energy purposes into a unique built-up structure, PV panels installed on greenhouses can represent an original chance for agriculture and the energy sector regarding renewable energies (Poncet et al., 2012; Tudisca et al., 2013). This opportunity has interested several areas around the world (e.g. Asdrubali et al., 2012; Gupta et al., 2012; Kadowaki et al., 2012; Pérez-Alonso et al., 2012; Sonneveld et al., 2010) such as Italy (e.g. Carlini et al., 2012; Castellano, 2014; Cossu et al., 2010, 2014; Sgroi et al., 2014).

Greenhouse structures, even if they are required to minimize potential drastic temperature changes (Marucci et al., 2015), define important activities to the primary sector, also permitted by favourable geographical and climatic conditions and highly-quality production and technology (Sethi and Sharma, 2007, 2008; Chou et al., 2004; Esen and Yuksel, 2013). Literature is rich in studies due to a wide availability of surfaces designated to greenhouse activities in Italy (Scarascia Mugnozza, 1995). Only over the past few years, greenhouses have been used for sustainable purposes, such as integrating them into systems to produce renewable energies (Marucci et al., 2012, 2014). One of these is to use solar radiation to produce energy and heat (Esen and Yuksel, 2013). PV plants can be placed on the roofs of greenhouse structures, leading to a new and diversified sustainable profile for agriculture (Messineo and Panno, 2008; Asdrubali et al., 2012; Carlini et al., 2012; Messineo et al., 2012; Mekhilef et al., 2013; Tudisca et al., 2013; Sgroi, et al., 2014; Marucci et al., 2016). Given the versatility of such technology and the ability to integrate PV panels on the roofs and facades of already existing buildings (Bonari et al., 2009), several benefits can be achieved (Frascarelli and Ciliberti, 2011). Nevertheless, national and regional administrations have deliberated limitations to avoid possible speculative occurrences concerning PV mounted on greenhouses. For example, the incidence of the rural income should be equivalent (or higher) than the income originating from energy production, when the PV power exceeds 200 kWp (or the percentage of PV coverage), whose

ground projection must not be greater than 50% of the total greenhouse area (GSE, 2012).

The transformation of the solar radiation into electrical energy has a twofold advantage: (i) recovery of the excess solar radiation in the greenhouse and (ii) production of electricity from renewable sources without negative environmental effects (Marucci et al., 2013, 2015). In some the hottest periods of the year, Italy is characterised by an excess of solar radiation if compared with the real requirements, reaching 50% of the incident radiation under the best conditions (Marucci et al., 2012). Despite the couple formed by photovoltaic energy and greenhouse structures presents many benefits, research is moving to design new systems that optimizes both energy and rural production (Colantoni et al., 2013; Marucci et al., 2017; Zambon et al., 2017a). In fact, several issues emerge associated to the effect of shading and the coverage of fertile soils in greenhouses (Gent, 2007; Kadowaky et al., 2012). The spatial distribution of shades is an essential parameter for choosing the best combination of PV panels and crops (Al-shamiry et al., 2007; Bojacá et al., 2009; Sonneveld et al., 2010; Dupraz et al., 2011; Gupta et al., 2012; Lopez-Marin et al., 2012; Urena-Sanchez et al., 2012).

Furthermore, one of the biggest problems encountered on these latest innovations, enabling multi-functionality, is the difficulty to manage and locate, at the national level, greenhouses on which PV plants are installed. Greenhouses and PV systems have not yet been mapped in a suitable database in Italy (Zambon et al., 2017a). Additionally, research studies have been limited to study contexts only at local scale (e.g. Sönmez and Sari, 2007; Cossu et al., 2010; Pérez-Alonso et al., 2012; Tudisca et al., 2013; Marucci et al., 2014; Sgroi, et al., 2014), without ever considering a larger scope. According Zambon et al. (2017a), currently an overall spatial database for predicting and monitoring the evolution process of the greenhouses, photovoltaic and their integration does not exist in Italy. The first purpose is to define the evolution of the PV mounted on greenhouse roofs, according to Energy count (E.C.). The latter allowed to place Italy, in 2009, to occupy the second position in the world rankings for the newly installed photovoltaic power (GSE, 2010a). In fact, the advent of E.C. has guaranteed the affirmation of PV technology in Italy through a highly profitable and innovative incentive mechanism (Frascarelli and Ciliberti, 2011).

The second goal was to examine the shading of PV panels of a prototype greenhouse, placed in Viterbo (in Central Italy) that enables an environmentally adapting to the intrinsic characteristics. The shading on crops is one of the major limits for the PV installation on the roofs of greenhouses because it causes problems regarding the usual sequence of agricultural activity (Pérez-Alonso et al., 2012; Tudisca et al., 2013). Until now, many research activities applied PV panels as covering material of greenhouses concentrated on flat structures (e.g. Battisti and Corrado, 2005; Pola et al., 2007; Marucci et al., 2017). Tunnel greenhouses which, due to their curved shape, do not lend themselves to accommodate easily PV panels on their coverage. The shading variation was analyzed inside the prototype greenhouse, by installing PV panels in a checkerboard arrangement. The transparent flexible PV panels are manufactured using mono-crystalline silicon cells, with an efficiency of 18%, incorporated into polymers with high resistance. The difference and distribution of the shading percentage will be examined regarding the surface area affected by the PV roof, the total area and the section of the greenhouse. Particularly, variations in the percentage of shading and the size of the shaded area will be observed on the twenty-first day of each month of the year, to observe the percentage of shading with the PV arrangement adopted during the year.

8.6.1. PV greenhouse

Viterbo is a central Italian city of about 70,000 inhabitants in the Latium region. Its province is also known by the name of Tuscia (Di Felice et al., 2014). Depending on its weather and solar radiation, Viterbo belongs to the zone D according the climate classification (on average 1501 kilowatts / hour a year). The latter catalogued zones the Italian municipalities according to the climatic classification, introduced by the Decree of the President of the Republic no. 412 of August 26, 1993, concerning the Rules for Designing,

Installing, Operating and Maintaining the Thermal Installations of Buildings for Containment of Energy Consumption, in implementation of art. 4, paragraph 4, of the Law of 9 January 1991, no. 10. The weather in Viterbo is closely related to that of the neighbouring areas of southern Tuscany, clearly differentiated from the southern part of the Latium region (Blasi, 1992). The climate is temperate and affects the influence of the sea. The summers are hot, and the winters are usually quite mild. Rainfall is largely concentrated in the fall and spring months with an average annual precipitation of about 800 mm, while the average annual temperature is 14.4 ° C. Despite some episodes of dispersive urbanization processes, Tuscia has maintained intact its agricultural landscape throughout time, which is still the driving force of its economy (Zambon et al., 2017b).

8.6.2. Evaluation of a prototype of PV greenhouse tunnel

As a first point, the issue of the situation of PV plants on greenhouse structures in Italy was addressed and discussed. Thanks to its favorable geographical position and climatic features, greenhouse structures and PV fields have been widely dispersed in Italy, identifying a relevant production quality and technology progress (Marucci et al., 2014). The study area considered has a significant presence of greenhouses dedicated to the cultivation of vegetables: if compared with the national context, the Latium region records approximately 20% of the surface (both total and in production) and of the total production (ISTAT census).

Available statistical databases are disposed by the National Institute of Statistics (ISTAT) and the Italian Energy Services Manager (GSE), with annual report. At regional level, GSE provides an Italian census regarding the number and the power installed (in kW) of PV plants on greenhouses for each E.C. during the last years. However, PV greenhouse plants have never been used as a landmark for the spatial analysis at the national scale (Zambon et al., 2017a). Despite the statistics of ISTAT and GSE, currently geo-referenced elements of greenhouse and PV structures do not exist for the whole Italy. The lack of large-scale spatial information restricts research fields for analyzing the national territory in terms of landscape impact, economy, energy and land consumption. Existing available spatial data concerning PV greenhouses are limited to local-scale study contexts (e.g. Tudisca et al., 2013; Cossu et al., 2010; Sgroi, et al., 2014; Pérez-Alonso et al., 2012; Sönmez and Sari, 2007); or furthermore, last research activities about greenhouses did not consider their spatial distribution, focusing for example on the spatial illustration of the annual energy requirements for heating them (Marucci et al., 2014).

A shading simulation was performed on a tunnel greenhouse situated at Tuscia University in Viterbo (geographic coordinates: 42° 25' 38" N, 12° 04' 51" E, 306 m above sea level). As already described, the context chosen is present in the Latium region, where there is an evident presence of PV greenhouses. Several indicators have been developed: the types of structure; shape and orientation of the greenhouse; incident radiation on the ground; the degree of absorption and reflection of the covering material; the size and position of the opaque structure. The latter are some of the main characters that are depended by solar radiation inside the greenhouse (Marucci et al., 2012). A PV greenhouse must be able to collect and store solar thermal energy keeping this heat for use on cloudy days and at night (Esen and Yuksel, 2013). Oriented for maximizing southern (Gupta et al., 2012), its well-isolated northern side has little (or no) glasses. Table 8.15 contains the characteristics of the greenhouse and its installed panels. The tunnel greenhouse is built with galvanized steel arches. It has a circular section (Φ = 100 mm) at intervals of 2 m, without openings for natural ventilation. The greenhouse has a width of 8 m, a length of 30 m and a height of 3.20 m (Figure 8.17).

The end caps consist of fibreglass with a grid (east) and an extractor (west) to keep the protected condition by forced aeration. The covering material is corrugated polycarbonate with fibreglass end caps and the greenhouse tunnel has an EW orientation. The semitransparent flexible PV panels:

- were installed on the cover following a checkerboard arrangement, 19 for each string;
- are made of mono-crystalline silicon cells, with a maximum efficiency of 18%, embedded inside a techno-polymer with high resistance;
- have a rectangular shape with 1.116 m x 0.165 m, with a thickness of 2 mm;
- are both parallel and equidistant to each other.

Table 8.15. Characteristics of the greenhouse and its installed panels.

Width	8 m	Voltage Rating (VMP)	4.2 V	Temperature coefficient P_{max}	-0.44%/°C
Max Height	30 m	Nominal current (IMP)	4.9 A		
Width	3.20 m	Open Circuit Voltage (VOC)	5.0 V	Temperature coefficient (VOC)	-0.33%/°C
Peak power (±5%) – P_{max}	20 W	Short circuit current (ISC)	5.5 A	Temperature coefficient (ISC)	0.05%/°C
STC: irradiance 1000 W m-2, cell temperature 25°C, AM 1.5					

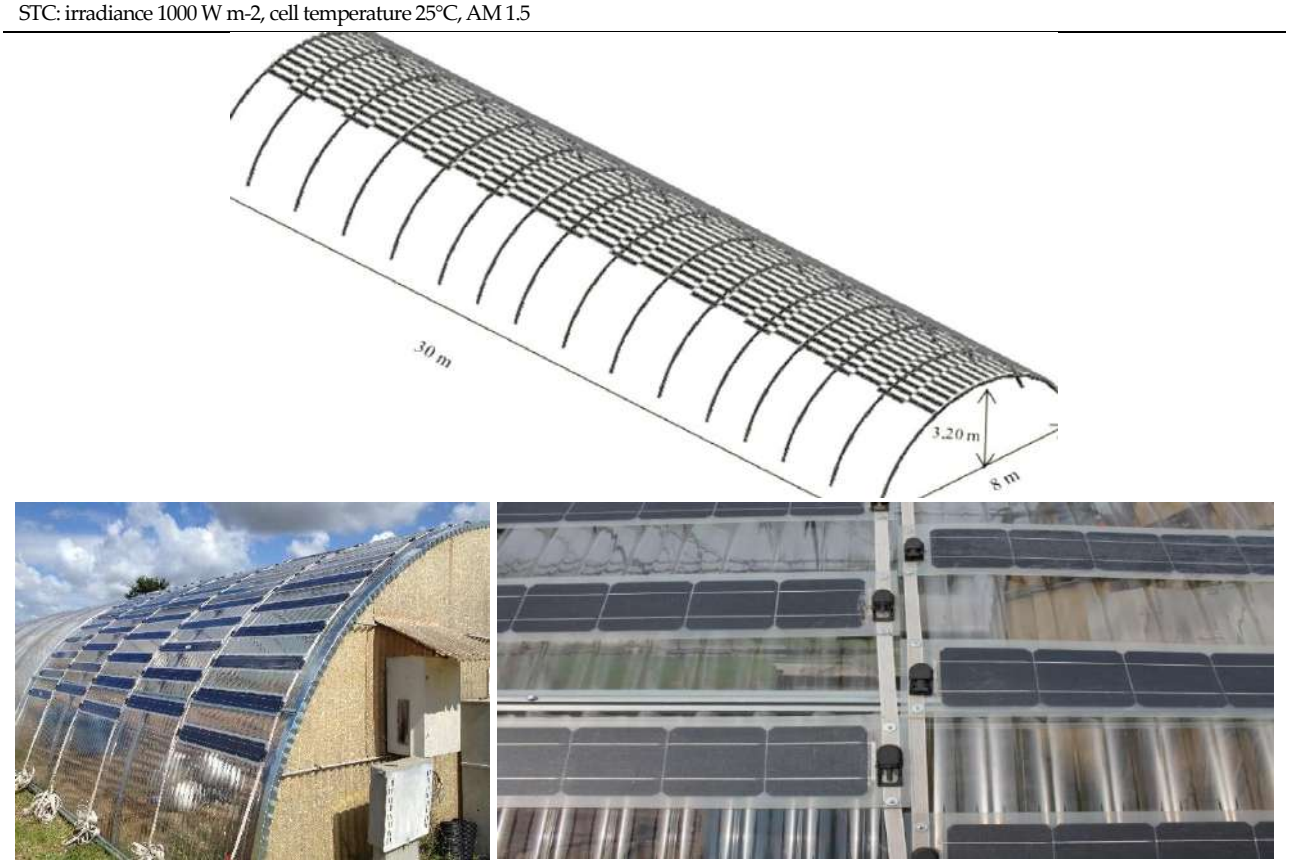


Figure 8.17. Semitransparent flexible PV panels in a checkerboard arrangement (top). Photo of PV panels installed on the greenhouse (left bottom) and their detail (right bottom) (Source: own elaboration).

The PV panels were placed on the cover of the tunnel greenhouse. The decision regarding the installation of partially transparent support panel for the PV cells was taken trying to reduce the shading on the roof of the greenhouse. Despite the significant annual variation of their zenith angle, PV panels result to be as much as probable orthogonal to the sunlight. The PV panels catches the direct solar radiation incident, of which only a small part passes in a diffuse form through the edges of the semitransparent support panels. Such kind of energy is insignificant in the shading calculation as the aim was to assess the consistency and shading distribution concerning PV panels.

The shading was simulated by means of the Autodesk® software. Especially, Autocad elementary 3D objects permitted to elaborate a three-dimensional model of PV tunnel greenhouse, extruding surfaces of revolution and objects. Each object has been related with its material with the equivalent radiometric features (e.g. reflectance transmittance, absorbance). Considering the geographic coordinates of the PV

greenhouses, Autocad software calculated sun's position, simulating the shading of PV panels on the roof and inside the greenhouse. The distribution and variation of the shading percentage were examined concerning (i) the surface area affected by the PV cover, (ii) the total surface area of the greenhouse and (iii) the section of the greenhouse.

8.6.3. Relevant observation on PV greenhouses in Italy

The presence of PV greenhouses in Italy has been remarkably successful in the last decade. Figure 18 report the main results achieved through a graphic elaboration using Gis program. Maps provided respectively the number of practices done and the power installed (in Kw) through each Energy count (E.C.), offering the evolution of PV plants installed on greenhouse in Italy, at regional level. PV greenhouses obtained a great success with the second E.C. in all Italian region. Such enthusiasm decreased during the following E.C., reaching high scores in the last E.C. The largest number of practices is concentrated in insular and Southern region but also in regions located along the Po Valley. Observing data concerning the power installed, Central and Southern areas (e.g. Latium, Apulia and Campania) and even regions located along the Po Valley reached the highest values. However, only Sicily and Calabria assisted an insistent installation of PV plants on greenhouses, both for number of practices done and the power installed, during the last years.

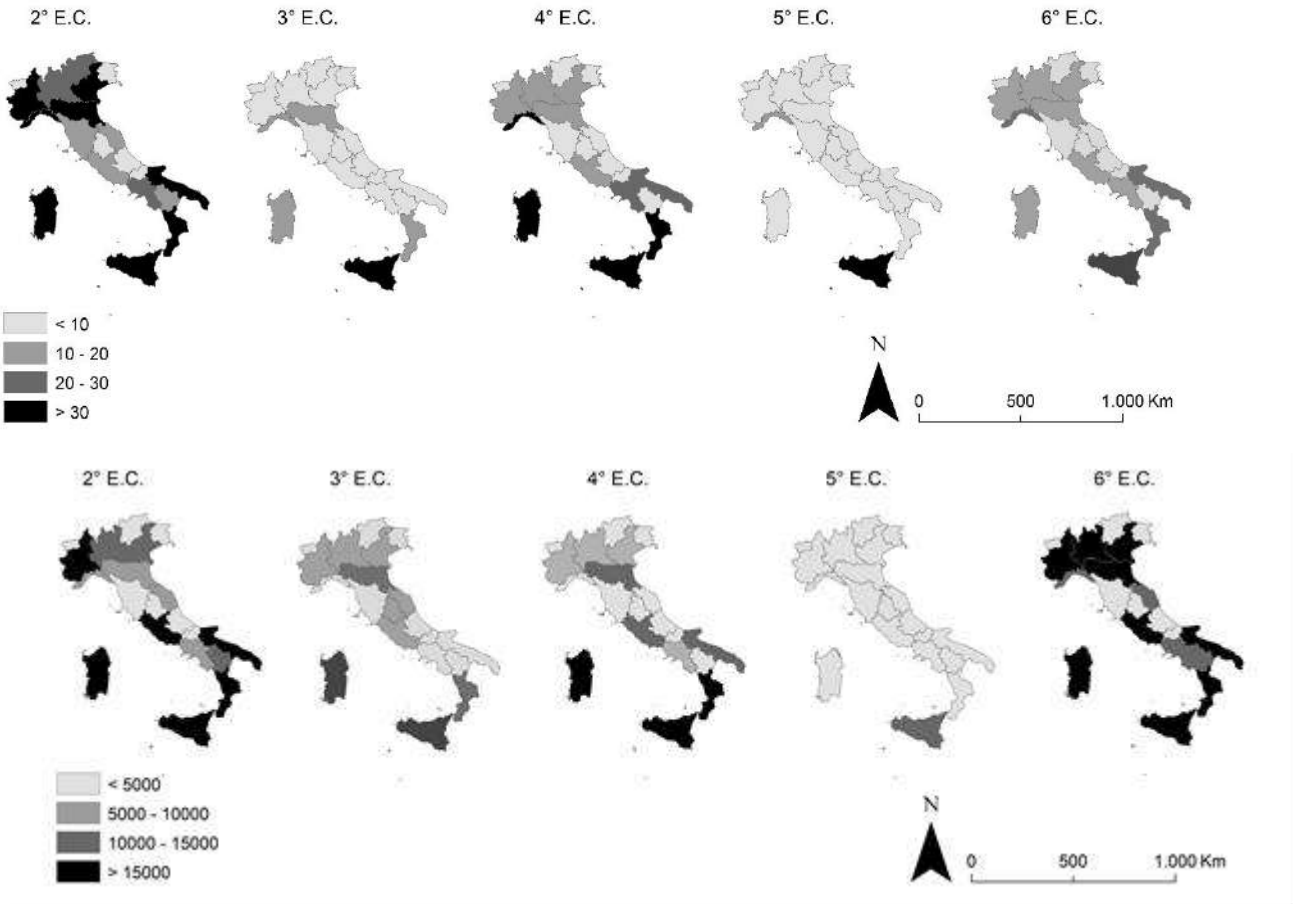


Figure 8.18. Number of practices for PV plants on greenhouses in each Energy Count (E.C.) (up panel) Total power installed designated for PV plants on greenhouses in each Energy Count (E.C.) (down panel) (Source: own elaboration).

Regional average value derived from the ratio of power installed (in Kw) on number of practices done during all E.C. in Italy (Figure 8.19). Through this spatial indicator, a regional observation along the Italic peninsula was carried out, inspecting which regions recorded numerous PV greenhouses having minor

power capacity (as Liguria) and those where PV greenhouse are few but very powered (as the regions of Piedmont, Latium, Lombardy, Sardinia and Calabria). Nevertheless, Sicily can be associated as the Italian region with the highest number of practises, even if its PV plants are of medium-size. Viterbo is collocated in central Italy, in a region in which there is a significant presence of PV greenhouses, exposing midway climatic conditions that well describes the Italian context. In fact, greenhouse cultivation can be considered well-developed in Latium region. In 2014, there were 43 requests practices for PV installation on greenhouses. It represents only 3% at national level, while, from the production point of view, greenhouses in Latium region contribute to 8% at the national level.

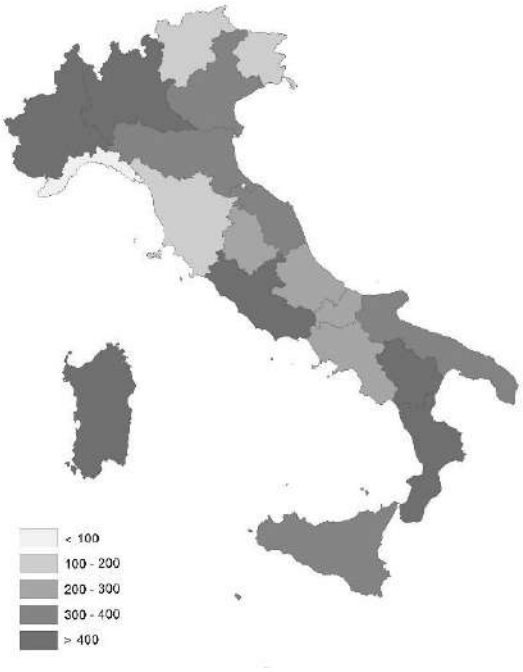


Figure 8.19. Regional average value from E.C. in Italy (Source: own elaboration).

The observations have focused especially during the most relevant periods in a year. In this means, the variations concerning the position of the shaded area and the evaluation of the shading uniformity have been calculated. Differences of the shading percentage and the size of the shaded area corresponded to the 21st day of each month in a year, with the intention of including solstices (in June and December) (Figure 8.20). In fact, solstices represent the most striking moments to understand how variations differ among them. Reporting the annual evolution, the elaborated calculations (North – West view) offered the distributions of shadows during the twenty-one days of each month (from 7:00 am to 5:00 pm). In the early and the last hours of the day, the shadows experienced a considerable longitudinal translation, although the traverse translation was insignificant. While in the second part of the day, the shadows assumed a regular inclination. Shadows were almost always inside the greenhouse in the middle of the day from March to September; while they were partly both inside and outside the greenhouse tunnel during the remaining months. On December 21st, at 14 a.m., approximately the 50% of shading was outside the greenhouse (Figure 8.20b).

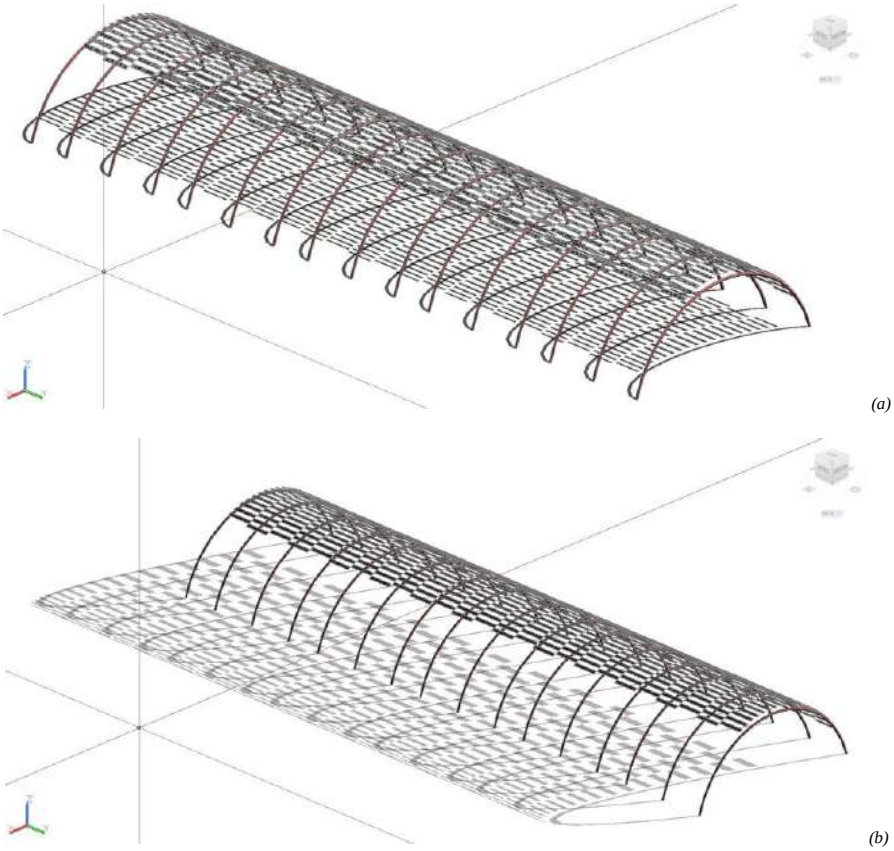
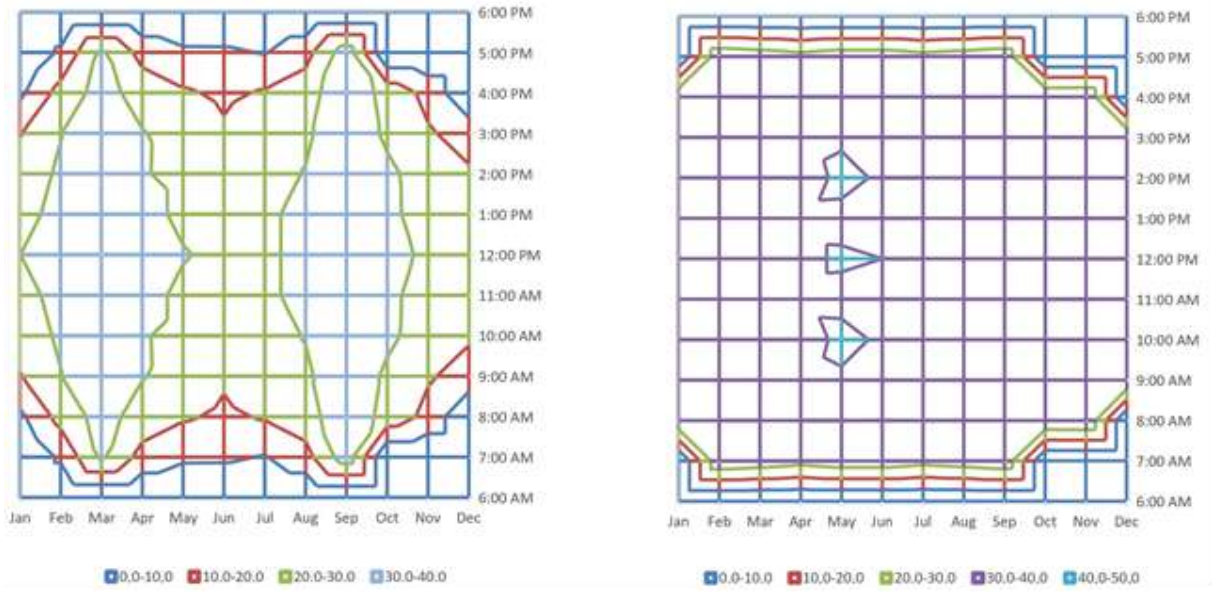


Figure 8.20. Axonometric projection of the experimental tunnel with the installed PV panels: June 21st, 2:00 p.m.; North-west view (a); December 21st, 2:00 p.m.; North-west view (b) (Source: own elaboration).

Further processing has calculated shading scores for each hour of the 21st day referring both to a single string (or surface of the tunnel greenhouse shaded by PV panels) and the whole covered area of the greenhouse (counting the non-shaded portion). A string of panels is defined by a width of 1.16 m. The shading percentage of PV panels under the string was kept constant during the day. During the solstice (in June and December), the shading percentage relating to the whole greenhouse surface expected a parabolic pattern with descending concavity. Although, the outcome associated to the whole greenhouse surface revealed the same persistent trend as the value under the string near the equinox (in March and September). Consequently, shading was concentrated in the central part of the greenhouse during solstices, while the surface was not shaded near the longitudinal walls, with a resulting decrease in the mean shading. Although, shadings distributed consistently over the entire surface of the greenhouse during equinoxes. The percentage of shading concerning the entire greenhouse surface was inclined to (i) match with the percentage shaded by PV panels under the string during equinoxes and to (ii) significantly decrease during solstices. The panels' shadows were distributed over the whole surface of the greenhouse. Confident effects on the shading uniformity can be observed over the crop during equinoxes. On the other hand, shadows of PV panels were concentrated, reducing the irradiation uniformity of the crops during solstices.

Scores concerning the shading percentage inside the greenhouse referred to the whole surface of greenhouse and the area corresponding to the width of a single PV string during all months of the year (Figure 8.21). In all months of the year, the percentage of shading never exceeded 40%. This rate, like all other shading percentages, was associated to the distance between PV panels as it can be increased by reducing the distance between the panels. Trend pointed out the highest values (> 40), during equinoxes

and solstices. This result meant for the smallest effect of the internal surfaces of the no-shaded greenhouse. For the agronomic assessment, the tendency of the percentage of shading was under the string, appearing persistent during the day and the year. Such consequence referred to the curvature of the roof of the greenhouse tunnels and the east-west orientation of the structure. A continuous tendency of shading on crops made it possible to select the performance during the year. Principally by providing a simple handling of the panels system, some PV panels can be removed from the cover when the solar radiation decreased under a definite threshold (< 10). The latter value occurred especially during cloudy days. A concluding question considered the uniformity of shading on crops and the intensity that were crucial in examining how shadows were distributed on crops. Shadows size inside the tunnel section was reported at 12:00 am on each 21th day in a year (Figure 8.21). The shadow of all panels was completely inside the greenhouse section in only four months (from May to August), when the size of the shadow along the section was between 0.10 m to 0.15 m. While, in remaining months, a considerable portion of shadow was outside the greenhouse due to the presence of PV panels, with a size of 0.31 m. The performance of several shades varied with the angle of elevation of the sun during the year. In the colder months (from October to February), the shading size along the section was much higher than in the warmer months. The difference of the shading size was subject to the angle of height of the solar rays and the tilt angle assumed by PV panels, because of the curvilinear shape of the section.



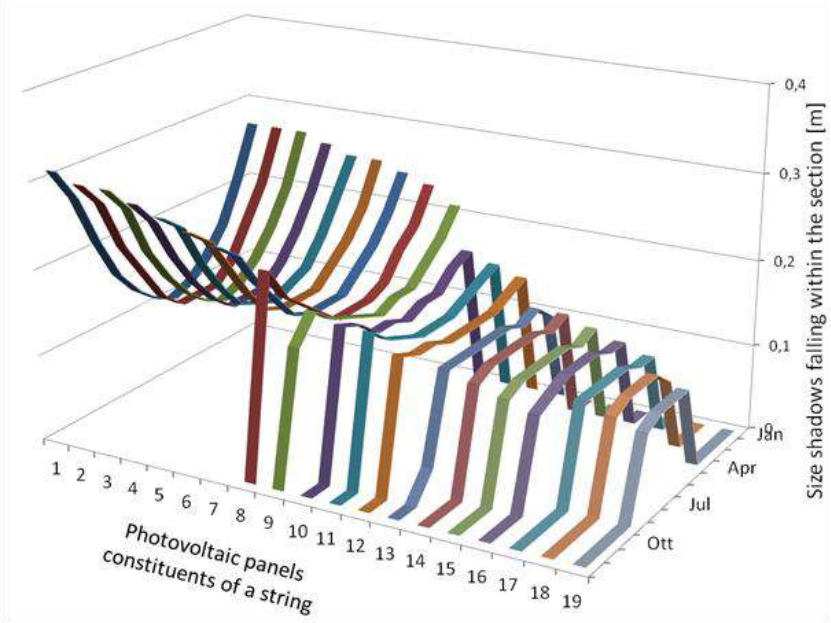


Figure 8.21. Shading percentage of both the string surface (in the left) and the entire greenhouse surface (in the right) in a year (top). Width of the shadows inside the tunnel section at 12:00 of the twenty-first day of each month (bottom) (Source: own elaboration).

8.6.4. Assuming tangible PV plants on greenhouses

Agriculture is one of more significant economic sector in Europe, especially in the Mediterranean landscape (Carvajal et al., 2006). Greenhouse plants have become more concentrated in several regions (Badgery-Parker, 2005), as Italy, Spain and Netherlands (Rogge et al., 2008; Sayin et al., 2006). In the latter countries, new commercial greenhouses are getting larger with a high-performance technology (Badgery-Parker, 2001), because they can protect horticultural products from environments agents (Carvajal et al., 2006) and allow profitable agricultural activities, with a continuous and controlled cultivation (Iribarne et al., 2007; Sönmez and Sari, 2007; Yano et al., 2010). However, they cause a considerable significant landscape, aesthetic and environmental impact (Rogge et al., 2008), e.g. regarding soil degradation processes. Especially concerning environmental competent, they implicate a high soil sealing and a consequential risk to land degradation processes (Burghardt, 2006).

A potential alternative, in contexts with a strong concentration of greenhouses, can be to integrate them with PV systems, leading towards a more sustainable development of an area (at least from an energy point of view) and avoiding the use of agricultural land for ground-mounted PV fields (Zambon et al., 2017a). An exploratory analysis of the evolution of PV plants on greenhouses can be useful for better describing contexts, with the purpose of studying and evaluating the sustainable development of a context, from the local to the national level. The lack of application and methodological tools in Italy demonstrated a progressing obstacle to research and innovation. Firstly, the regional distribution of PV greenhouses in Italy was explored. This regional information has not never been considered in others research studies, stopping the analysis at a very local level (such as in Italy Tudisca et al., 2013; Cossu et al., 2010; Sgroi, et al., 2014). The importance of having an overall (statistical and spatial) database about PV greenhouse plants at a detailed level, extended for an entire country as Italy, enables the prediction of further damage, a constant monitoring of an area both in economic, environmental and energy terms, a series of actions and policies planned to prevent future negative impacts and manage effectively the territory. The detection and localization of greenhouse plants characterises an important chance for policy-makers to have to take the appropriate decisions (Carvajal et al., 2006). Continuous monitoring must be guaranteed by means of the GIS programs by providing an effective and useful spatial analysis. GIS technology allows to collect,

process, retrieve and display spatial data (Burrough and McDonnell, 1998; Rogge et al., 2008), combining and integrating them to produce information (Lee et al., 1999). The existing studies emphasize that GIS elaboration can support policy-makers in addressing key issues (Peccol et al., 1996) and to take effective decision-support systems that deal with the territorial planning (Bell, 2001; Bryan, 2003; Palmer and Hoffman, 2001).

In addition to the limited availability of existing databases in Italy today, the shading distribution of the PV roof of a prototype tunnel greenhouse, due to its curved shape, do not lend to accommodate easily PV panels on the coverage. In fact, shading is one of the major limits for the PV installation on the roofs of greenhouses (Tudisca et al., 2013; Pérez-Alonso et al., 2012). The spatial shading variations in the greenhouse during a year can be considered a suitable indicator for selecting the greatest combination of PV panels and crops present, with the aim to guarantee both energetic and production activities (AlShamiry et al., 2007; Lopez-Marin et al., 2012; Urena-Sanchez et al., 2012). Comparing to other studies, the choice of using PV panels in tunnel greenhouses resulted to be interested. The choice of the covering shading on the spectral distribution of solar radiation entering to greenhouses, the kind of material and further properties (e.g. radiometric and thermal) of the greenhouse is crucial for defining relevant technical structure details, environmental factors and internal climatic environments (Kittas et al., 1999; Papadakis et al., 2000). The latter need to be considered with the goal of relating them with issues, such as spatial shading variations in the greenhouse, heating and ventilation, the energy demand for the illumination, which can be take out from solar contribution using greenhouse prototypes (Papadakis et al., 1998; Kavga et al., 2016; Trypanagnostopoulos et al., 2017).

Evaluating the shading differences due to transparent and flexible PV panels installed on the roof of a tunnel greenhouse brought out an added value to the present research. Several researches on PV greenhouse usually used conventional flat hard or planar flexible modules (Al-Ibrahim, Al-Abbadi, & Al-Helal, 2006; Kadowaki et al., 2012; Pérez-Alonso et al., 2012; Sonneveld et al., 2010; Yano et al., 2010, 2014). However, recent studies offered further possibilities for solar cell applications in greenhouses, such as trying to implement silicon photovoltaic panels, mounted in two ways (fixed and mobile) on greenhouse roofs (e.g. Urena-Sanchez et al., 2012; Allardyce et al., 2017; Trypanagnostopoulos et al., 2017). In fact, with partially semi-transparent PV panels, the shading on the roof of the greenhouse has been reduced. With the arrangement of the PV panels assumed, the shading in the middle of the day remained almost completely inside the greenhouse from March to September. Although, it is partly inside and partly outside the tunnel greenhouse during the other months. With the PV cover implemented during a year, the shading percentage was never more than 40%. The shading rate of PV panels under the string was constant during the day. The percentage of the entire surface of the greenhouse was unchanged during equinox, even though the tendency of the shading rate became a parabola with downward concavity during the solstice. It is crucial to assess the effect on crops of the tendency of the shading scores under the string, which was relentless for the duration of the day and for every day of the year. The constant trend of shading on crops made it possible both (i) to select the sequence of the crops and (ii) also to remove them, with simple handling of the panels of the system, when the solar radiation fell under a definite threshold (such as cloudy days).

Likewise, the shading uniformity was concerned as a concluding question addressed in the research: it has significantly increased during the colder months (from October to February) as it depends on both the height of the sun and the angle of the PV panels, which varies along the tunnel section.

8.7. Designing a PV greenhouse in a floristic context

Renewable sources can be used in the agricultural field (Bulgari et al., 2015). Among these, the most widely used are: (i) photovoltaic panels and (ii) micro or small wind turbines to produce electricity, and (iii) solar-thermal for the heat production (e.g. Panwar et al., 2011; Demirbaş, 2006; Kralova and Sjöblom, 2010). In recent years, thanks to government grants, applied technologies have undergone rapid evolutionary processes, leading to new efficient and economically-competitive products usable also in the agricultural sector (Carlini et al., 2012; Cossu et al., 2014).

The possibility of using solar greenhouses with a dual purpose, such as for both energy production and floricultural products was examined. Among the systems of exploitation of renewable sources of energy, photovoltaic (PV) system has been strongly studied and analyzed over the last five years, as well as by several scientific research activities (Stanhill, 1992, Celik et al., 2009). Building PV greenhouses is technically feasible from the construction point of view; on the contrary, realizing solar greenhouses able to guarantee an efficient agricultural production, in addition to electricity production, is far from to be a simple task (Parker, 1991; Yano et al., 2005). Currently the application of greenhouse technology in floriculture is rapidly expanding around the world (Ganguly and Ghosh, 2007). Successful greenhouse production is derived from the possibility of (i) providing a favorable ground for the cultivation (Russo et al., 2014), (ii) ensuring a controlled microclimate, (iii) avoiding adverse weather conditions (Xu et al., 2014), (iv) preventing pests and diseases (Yang et al., 2014) and (v) thereby improving the quality of the crop (Pérez-Alonso et al., 2012). Greenhouse crops are one of the most intensive activities of agricultural sector (Djevic and Dimitrijevic, 2009) in terms of production and energy consumption and operating costs (Canakci and Akinci, 2006; Sharma and Sethi, 2007; Singh et al., 2007). Agronomic research, construction technology concerning PV greenhouses and the choice of transparent roofing materials are now increasingly oriented to reduce artificial energy usage to contain production costs and to reduce environmental impacts (Vox et al., 2010; Marucci et al., 2011; Campiglia et al., 2007; Marucci and Pagniello, 2011; Hanan, 1998; Nelson, 2003).

Cited article

Colantoni, A., Monarca, D., Marucci, A., Cecchini, M., Zambon, I., Di Battista, F., Beruto, M. (2018). Solar Radiation Distribution Inside A Greenhouse Prototypal With Photovoltaic Mobile Plant And Effects On Flower Growth. Sustainability, 10(3), 855.

Since greenhouses occupy agricultural land (Zambon et al., 2017d), it is supposed that the integration of production plants of solar energy on the greenhouse roof can be the most sustainable solution (Cuce et al., 2016). However, some determinants must be considered. The factors that strongly influence the design of a solar greenhouse for floricultural use are: (i) the shadow projection of PV panels on the ground; (ii) the amount of photosynthetically active radiation present within the structure; (iii) the design of protected installations, able to ensure sufficient flexibility and to allow changes in cultivation target in relation to changing market demands (Kozai et al., 1999; Huang et al., 2008; Marucci et al., 2013; Stanghellini, 2010; Tanaka et al., 2009). In fact, farmers, who have a limited area for PV systems, are forced to use the roofs of greenhouses, causing many problems related to day-lighting, such as loss of color and smaller size of products collected (Cuce et al., 2016; Yano et al., 2010). In those circumstances, it must be concluded that the main problem of greenhouse system consists of the entity of the economic investment requested at the beginning (Minuto et al., 2011; McDonald et al., 2005; Bulgari et al., 2015). This commitment seems more compatible with industry rather than with the traditional agriculture. The cost of a greenhouse equipped lies between € 40 and 200 / m^2 depending on the climatic area (where the structure is built), the technological level and chosen infrastructure, as well as the type of crop to be produced. These factors completely affect business models that arise. In fact, the depreciation cost imposes an ultra-intensive production system (with a high load of labor and energy) and the choice of high-yield crops and with

considerable added value. In a mixed system, such as that in the present work, where a part of the investment concerns the photovoltaic chain, also the less intensive and extended production systems become available to a wider range of cultivated species, from an economic point of view.

In this perspective, it might be expected an enlargement of the cultivable species. Feasibility studies could also concern crops not yet well considered due to the lack of profitability. In a protected environment (due to the controlled microclimate that is recreated in a greenhouse), the light is a critical and limiting factor for most of the cultivated species, like others, such as the temperature or the relative humidity (Stanghellini e Heuvelink, 2007). In recent years, new opportunities in the energy market and the incentives related to the construction of photovoltaic plants, as well as the progressive reduction of purchase costs of most PV materials, have encouraged the implementation of PV systems mounted on greenhouses (in their total or partial replacement) (Danny et al., 2009; Marucci et al., 2013; Carlini et al., 2012). The acceleration of the market has given rise to problems of coexistence between the electric and the agricultural production, in competition with the same source of energy, as noted in the recent past (Parker, 1991 Yano et al., 2005). The biggest problem that designers and farmers must face is the light inside the greenhouse (Minuto et al., 2011). PV panels projects shadow cones on the ground: the amount of photosynthetically active radiation reaching on the crop cannot depend only on the limiting conditions imposed by the photovoltaic installation, but also the actual interest that that culture has for the market and the product quality obtained (Kozai et al., 1999; Stanghellini and Heuvelink, 2007; Bulgari et al., 2015). Developments of materials, and still more the tax legislation for access to the forms of incentive, have produced the progressive change of PV installations on greenhouses (Minuto et al., 2011). It has gone from structures specifically built as a function of the PV system with mono-pitched or bi-pitched roof, 100% covered by totally opaque PV panels, up to realizations gradually more attentive to the needs of agricultural crops. This type of planning is leading to the creation of more luminous greenhouse structures than those currently available in the market (Minuto et al., 2011). In addition, efficient solutions for air circulation and cooling of the PV panels have been introduced, providing "modular" solar panels with roof structures of the greenhouse (Minuto et al., 2010).

Climatic conditions inside a greenhouse, in which 50% of its roof surface has been replaced with mobile PV panels, able to diverge the light energy collection surface according to the degree of insolation were surveyed. The purpose is to detect the shading effects of PV system on some flowers growth (iberis, mini-cyclamens and petunias), guaranteeing an optimal underlying environment in most lighting conditions and letting through more light when it is required for the needs of crop plants (or in cloudy weather). Furthermore, it is expected that this system also delivers an income integration to farmers.

8.7.1. Geographical and structural characteristics

The greenhouse prototype is located at the Regional Institute for Floriculture in Sanremo (IRF), Liguria region, North-East Italy (geographical references: 43°49'3''N - 7°45'50''E with an axis of orientation of the roof ridge of 351°N) (Figure 8.22). The greenhouse chosen for the experimental study was built in 1985. It is a glass single span greenhouse with ridge ventilators, with the following dimensions: 9 m width; 12.44 m length; 3.53 m height at the sides and 5.15 m ridge height.

On the greenhouse roof, an innovative PV solar system (3016 W) with movable panels has been mounted. It consists of twenty-six PV fixed modules and twenty-six PV mobile modules mounted on the top towards to the east. The PV modules have a power of 58 W. Twenty-six fixed glass panels were removed and, inside the greenhouse, a rail system was set on which the movable panels have been installed. The movement was guaranteed by a ratchet electric tire (Blinky brand, mod. 49463-02/6) with 12 V and a power of 150 W. An inverter Abb Power One PVI 3.0 Out Tl was installed for the network connection, having 3000 W with dual input Mppt CEI 0-21.

Different challenges should be faced during the design of the prototype. The moving system of panels initially encountered some difficulties during its installation and calibration, due to the inclination of flap height and weight of the underlying panels block that would have to run on the rail. In mid-May 2016, the prototype of PV mobile panels plant was completed.

The proposed system allows to control the shading in an active way, continuing to have a high-quality photovoltaic production (compared to a standard system with fixed shading to 50%) as: (i) during the sunny days, when the PV production is greater, it is possible to use the maximum shading of 66% (which exhibits greater active area compared to the fixed one); and (ii) in cloudy days, there is a certain loss of electrical energy (compared to a standard system with shading 50%). But, on the other hand, there is an advantage from the viewpoint of the greenhouse performance, with a greater light passage (33% of shading). The movement system allows the variation from 33% to 66%, by translating the PV mobile module (only about 25 cm) placed below the fixed one.

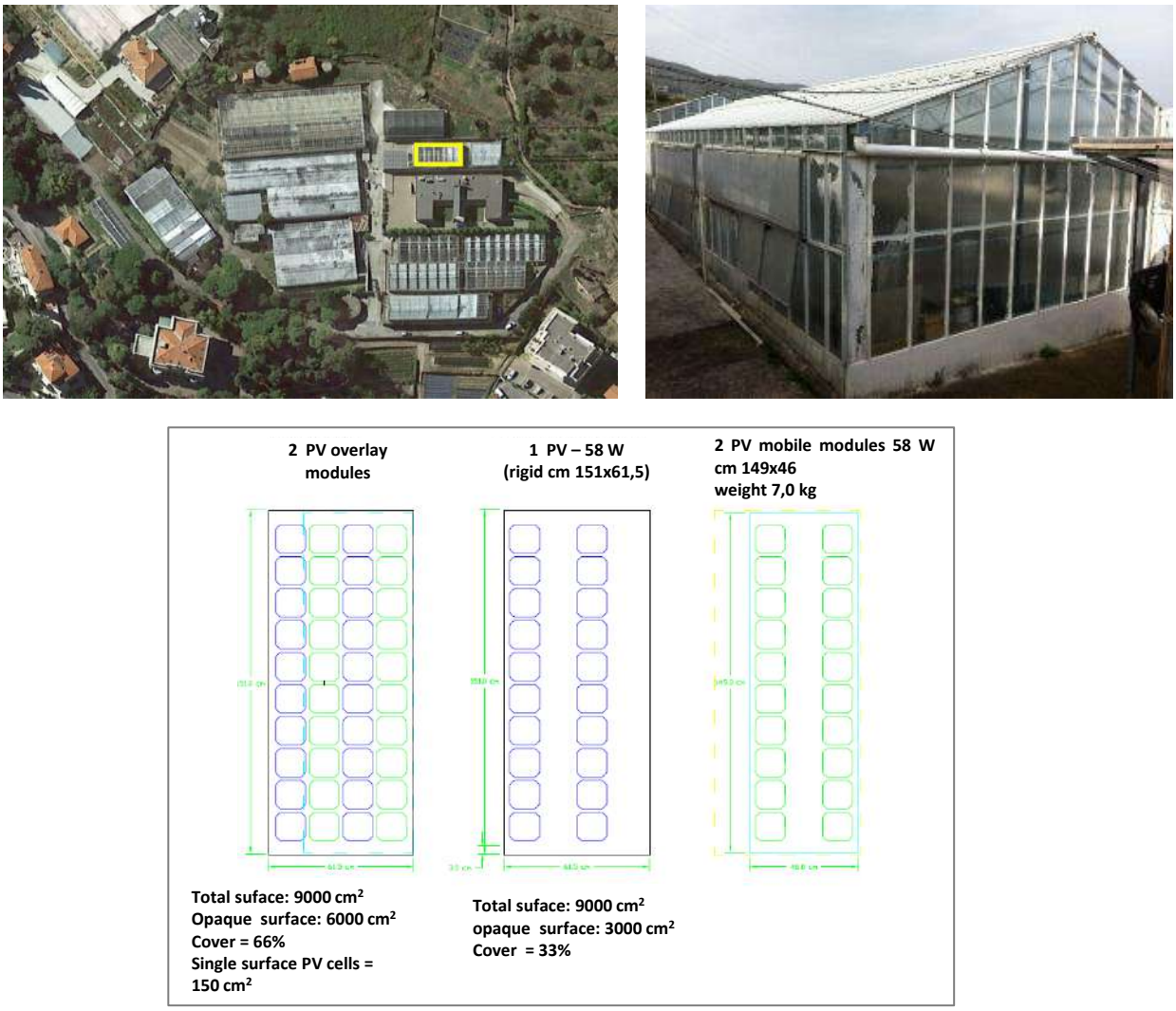


Figure 8.22. Location of the greenhouse model (left top) and its external overview (right top). Technical drawing of PV panels with variable shading (bottom).

8.7.2. Environmental measures

The environmental conditions of the greenhouse during the experimental trial were assessed by data on temperature and relative humidity (T° C, RH%) and lighting measurements (PAR, Radiation Total, illumination, UVA). These latter ones were performed by means of two sets of sensors, located in the two different cultivation areas (under photovoltaic area-PV and out of photovoltaic area- Control).,

A computerized system (μAgricomp-DL - Agricontrol SnC, 17031 Albenga SV, Italy) was used for the measurement and registration of temperature, relative humidity and brightness, global solar radiation, PAR and UVA radiation. The photometric and radiometric probes used are professional instruments (Delta Ohm, 35030 Caselle di Selvazzano, Padova (PD) Italy) as follows: LP PHOT 03 (measuring range of 0-100000 lux with a resolution of both 40 lux from 0 to 10,000 lux and 400 lux from 10,000 to 100,000 lux): it measures illuminance (lux), defined as the ratio between the luminous flux (lumens), passing through a surface, and the surface area of the area considered (m^2); LP RAD 03 (measuring range of 0-1.000 W/m^2 with a resolution of 1 W/m^2 from 0 to 250 W/m^2 and of 4 W/m^2 from 25 to 1.000 W/m^2): it measures the irradiance (W/m^2) defined as the ratio between the energetic flux (W), passing through a surface, and the surface area of the area considered (m^2) in the spectral region VIS-NIR (40 nm - 1.050 nm); LP PAR (measuring range of 0-1.500 ◎Mol/m^2/sec (PPF: Photosyntetic Photons Flux) with a resolution of 1 PPF from 0 to 250 PPF and 6 PPF from 250 to 1.500 PPF): it measures the number of photons in the spectral region ranging from 400 nm 7200 nm, arriving in a second on a surface; LP UVA 03 (measuring ranges from 0 to 200 W/m^2 with a resolution of 1 W/m^2): it measures global irradiance in the UVB spectral region on a flat surface (W/m^2). Particularly, the spectral sensitivity of the instrument is centered at 305nm with a bandwidth (FWHM) of 5 nm. Data were analyzed by using the statistical software Statgraphics Centurion XVI. To better highlight the reduction of brightness under PV condition, α variable was considered as follow:

$$\alpha = ((xc - xpv)/xc) * 100$$

where:

xc= brightness measurements (illuminance, irradiance and PAR) at control conditions

xpv = brightness measurements (illuminance, irradiance and PAR) at PV conditions

When $\alpha = 0$ the light conditions are the same for the two treatments (control and PV), greater value of α indicated the reduced brightness conditions achieved under PV.

8.7.3. Plant materials and agronomical trial

Plant growth under the "model greenhouse" was followed to infer the agronomical performance of different crops chosen as plant models. For this, plants grown directly under the PV panels were evaluated and their growth was compared to the behavior of a similar plant grown in the same climate greenhouse but out of the PV panels. The agronomical trial start at week 29/16 (18th July 2016) and ended 38/16 (22 th September 2016), (total 9 weeks of cultivation).

Mini-cyclamens, iberis and petunias have been chosen based on seasonal availability, their importance for the floristic market and their adaptability to the environmental conditions. The seedlings were purchased by Sentier (31010 Moriago della Battaglia, Vidor -TV) and arrived at the institute at the week 28/16. The following varieties were considered: Ciclamen persicum 'S.S. Verano®' Dark Violet, Petunia grandiflora 'Nana GP F1' red and Iberis sempervirens 'Montreaux' White. Before the beginning of the experiment, seedlings were transferred to 12 cm diameter pots, filled with "Pomix 2" (Turco Silvestro S.N.C., Albenga, SV - Italy) which is a substrate containing Irish peat, blond peat, pumice stone (3-8 mm), clay and slow release mineral fertilizer (Figure 8.23c, d, e). Water and nutrient supply have been guaranteed by an automatic drop-flow irrigation system (irrigation on alternate days, 2 times a day; fertilizer ratio N: P: K equal to 1: 05: 2).

Figure 8.23. Experimental stage: complete panel diagram (overlapping panels) (a); complete mobile PV system (maximum capitation of light radiation) (b); seedling on arrival in commercial plug tray (c); plants in the greenhouse prototype (d); plants during the trial (e).

Thirty plants by species (90 in total) were evaluated for testing; one half was placed under the PV panels; the other half was placed under normal lighting conditions. For each treatment (PV and control) 5 plants have been considered and three replications were performed. Data were statistically analyzed according to multifactor analysis of variance (Statistical software Statgraphics Centurion XVI).

The following parameters have been considered to evaluate the plant growth:

- plant height;
- plant diameter;
- number of flowers/plants. In the case of iberis, the number of flower buds was counted since no blooming was scored for both treatments (PV and control).

8.7.4. Data distribution inside the greenhouse

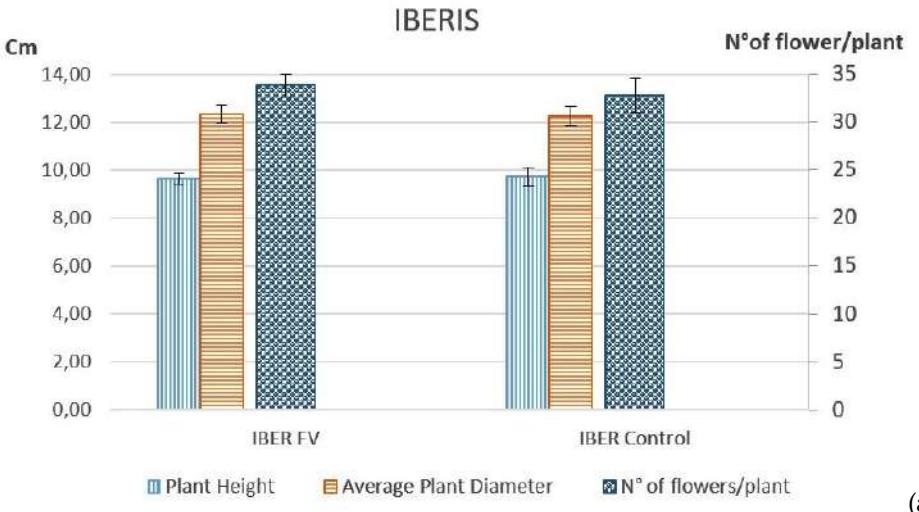
To highlight the different light condition under PV treatment, the significant reduction of brightness values at week 37 recorded also for control treatment could be ascribed to a particularly cloudy period, which influenced the incoming radiation in the greenhouse; this effect has also been confirmed with the temperature data. As expected, the PV conditions reduced the brightness. However, a different reduction could be scored according to the light measurements. Under the experimental conditions PV panels on a part of the greenhouse roof and orientation and structure of the prototype , it was possible to infer that:

the amount of incident light per unit area is about two times higher under the control area compared to the PV treated area; the total radiation (RAD) and the photosynthetically active radiation (PAR) were reduced of about 30% and 20% respectively under PV treatment.

8.7.5. Crops production and relation with greenhouse plant

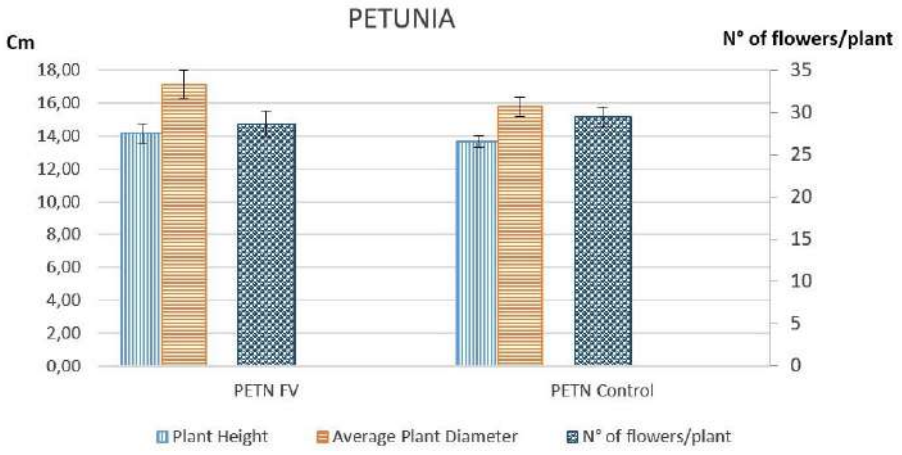
No blooming was recorded for iberis over the trial period. This was true for the control and for the seedling grown under PV. From the count of the flower-induced buds, however, no differences were detected between control and PV treated plants. In addition, the vegetative growth was not influenced by PV treatment (Figure 8.24a, b) A similar agronomical behavior was detected for petunias, for which a complete blooming was, vice versa, observed (Figure 8.24c, d). Then, it was inferred that the flowering lacking in iberis was rather due to the high greenhouse temperature (maximum temperatures up to 40 °C and, for the trial period always between 25 and 35 °C) and no influence of the prototype could be ascribed.

Mini-cyclamen growth was affected by PV system (data not shown). Indeed, under PV prototype, an enhanced plant diameter and a reduced flowers/plant could be observed (Figure 8.24e, f). Besides, a flowering precocity, about one/two weeks, was also detected.



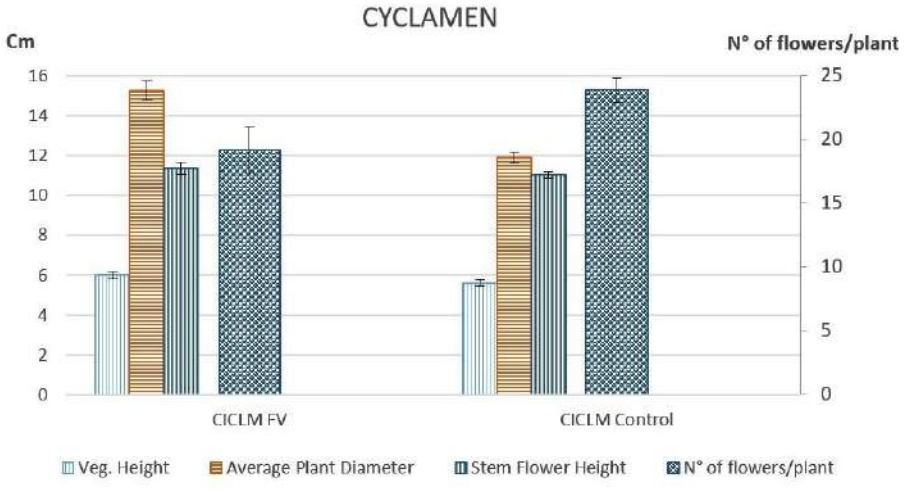
(a)

(b)



(c)

(d)



(e)

(f)

Figure 8.24. Iberis: analysis of plant growth parameters at the end of the trial (a); Iberis - control and plants under

PV compared (b); Petunia: analysis of plant growth parameters at the end of the trial (c); Petunia - control and plants under PV compared (d); Mini-cyclamen: analysis of plant growth parameters at the end of the trial (e); Mini-cyclamen - control and plants under PV compared (f).

8.7.6. Opportunity for existing greenhouses

The success of PV plants mounting in greenhouses derives from the chance to achieve a strategic and ingenious cultivation through environmentally-controlled greenhouses (Kadowaki et al., 2012), enabling a safe and continuous production, safe and continuous (Rogge et al., 2008; Ganguly and Ghosh, 2007; Cuce et al., 2016). In the modern agriculture, greenhouses embody technological solutions aimed at increasing quality and productivity of crops (Pérez-Alonso et al., 2012). Specifically, the application of greenhouse technology in the floriculture sector is recording a strong growth trend around the world (Ganguly and Ghosh, 2007).

Regions that enjoy plenty of solar radiation, such as Italy, can take advantage of solar energy to provide clean and renewable energy (Ganguly et al., 2010). Excluding the installation of PV panels on agricultural land, as happened in the past resulting in an effective land degradation and soil sealing (Delfanti et al., 2016; Marcheggiani et al., 2013), PV panels applied on the roofs of greenhouses can be considered an attractive solution (Kadowaki et al., 2012; Ganguly et al., 2010). In this way, greenhouses can make sure a rural multi-functionality, given by the production of additional energy, as a result of the combination of PV modules on their surface (Pérez-Alonso et al., 2012; Tudisca et al., 2013; Marcheggiani et al., 2013). Conversely, the mounting of this kind of PV plants inevitably generates a shadow inside the structure (Kadowaki et al., 2012; Minuto et al., 2011; Cuce et al., 2016; Yano et al., 2010). Therefore, it is necessary to prevent the shading since it does not cause an interruption on plant growth (Pérez-Alonso et al., 2012).

Given the wide availability of land occupied by greenhouses in Italy, a thorough study on the optimization of PV greenhouse systems may be useful consequently to: (i) promote a new sustainable profile for the Italian agriculture; (ii) use clean and renewable energy; and (iii) ensure a controlled, safe and unceasing flower production (Mekhilef et al., 2013; Tudisca et al., 2013; Asdrubali et al., 2012; Sgroi, et al., 2014; Messineo et al., 2012; Messineo and Panno, 2008).

The opportunity to productive recovery of existing greenhouses is a complex aspect, which provides an interdisciplinary effort. The results obtained brought out that issues concerning the quantitative and qualitative reduction of the production of the plant species chosen for the research cultivation in the PV greenhouse did not emerge. Considering for the greenhouse model, the interested part of the PV greenhouse coverage and its orientation (almost perfectly N-S) allowed light to enter without being disturbed by the presence of PV panels during the day. The analysis of the brightness data, with reference to the parameters of illuminance (lux accidents), global radiation and PAR (Photosynthetically Active Radiation), has provided values that were statistically higher in the sector, without being influenced by PV panels, in a greater extent for lux accidents (with two times higher values) and lesser for global radiation (30%) and PAR (20%). These conditions have allowed plants to grow and reach anthesis (except for the iberis, not bloomed in both thesis) without great alterations from the standpoint of the marketability of the commercial product. For the cyclamen, some slight differences were recorded due to an increase of the surface of the light capitation with a greater development of its vegetative part in the shaded area and fewer blossoms, but without affecting its commercial quality. Indeed, it is well known that light profoundly affects the plant life. The three most important reactions of plants to optical radiation are: photosynthesis, phototropism, photo-morphogenesis. Photosynthesis is one of the most important biochemical processes which converts energy into chemical energy. In general plant physiology, the term Photosynthetically Active Radiation (PAR) refers to the radiation in the range of wavelengths between 400 nm and 720 nm which are useful for the photosynthesis (Salisbury F.et al., 1994; Taiz L. et al., 1998). The green radiations (about 550 nm) have been shown important to yield the greatest productivity and efficiency in greenhouses

grown plants, although differences could be scored according to the species. In the experiment, plants grown under PV conditions were always subjected to a lower PAR compared to the control, and the values allowed an efficient photosynthesis process being the first three weeks of cultivation more favourable. The effect of blue light (380-520 nm) could account for the somewhat phototropism and photo-morphogenesis effect above described for mini-cyclamen plants. Extensive studies would be more appropriate to verify the effect of a more extensive coverage, within restrictions imposed by the Ministerial Decree 05/05/2011 which limits the coverage of greenhouse roof with PV modules for a maximum of 50% of the total area. It affirms that "greenhouses, after the intervention, must present a relationship between the projection on the ground of the total area of the PV modules installed on the greenhouse and the projection on the ground of the total area of the greenhouse itself does not cover more than 50%". This condition does not apply to greenhouses that have achieved qualification by the entrance into force of the Decree (13 May 2011), in pursuance of the order by TAR of the Latium Region n. 2890/2011 by which the effectiveness has been suspended art. 14, paragraph 2, following the Ministerial Decree of 5 May 2011). A solar system, such as the one proposed in the work, capable of varying light energy collection surface in relation to the degree of sun exposure, has certainly the agronomic benefit of being able to shade the underlying environment in conditions of excessive brightness and to let pass more light when it is required for the purposes of cultivated plants (or in cloudy weather). A commercial development of such system would have to be considered, even if the awareness in using solar energy as a supplement to the income from the floricultural production continued to be present.

8.8. Sustainability in the wine sector

In Italy, the only driving subdivision in the agricultural sector is the wine industry (Mariani and Vastola, 2015). Wine products experienced a strong interest in the last years, especially due to its economic market. Furthermore, thanks to the reform concerning the common wine market organization (CMO) (European Commission, 2008), a lot of rural abandoned surfaces have been reconverted for viticulture practices in Italy. Since the European Commission came out the expenses for the national support plan at the European level in recent years, Italy is the country that spent more (€11,700 for 28,000 hectares under renovation for a total of €325 million) than France (€4,300 for 51,000 hectares) and Spain (€3,700 for 47,000 hectares). The expansion of the wine market has brought landscape along changes and/or homogenization, particularly in areas where this crop can be most suitable. The establishment of agro-energy districts can become a cutting-edge business in the modern agricultural sector, implementing new strategies, even of a sustainable nature, by networking several actors. Following previous works (Tenerelli and Monteleone, 2008), the present work evaluated how the Italian landscape has changed in just over a decade (2000-2012), estimating how much biomass from the wine industry can be obtained.

The methodology followed various steps. Firstly, a descriptive stage of the wine sector was applied in Italy, in terms of production data concerning both offer and foreign trade. Secondly, a spatial exploration was performed by observing landscape changes and land-use dynamics. In this respect, the Italian regions that have witnessed a greater growth for the wine sector in the last years emerged. Veneto region was one of these contexts and therefore was investigated. An estimation of the amount of biomass that can be obtained from the contexts considered allowed an assessment of energy and potential mechanization processes, as well as an economic evaluation.

Cited article

Zambon, I., Colantoni, A., Cecchini, M., Mosconi, E. M. (2018). Rethinking Sustainability Within The Viticulture Realities Integrating Economy, Landscape And Energy. Sustainability, 10(2), 320.

Despite an incessant decline of the primary sector, mainly in peri-urban areas (Duvernoy et al., 2018), Italy experienced a growth rate in the wine sector. The Italian country embodies the second largest wine producer recording a world market share of 16.4% and a turnover of € 10.5 billion (Mediobanca, 2016; Annunziata et al., 2018; Zhu et al., 2016). The rising demand, even foreign, of Italian wine resulted into a strong increase in recent decades (Mariani and Vastola, 2015). The growing devotion that wine sector dedicates on quality allowed to create a reference point for data and analysis of the Italian wine heritage (Annunziata et al., 2018; Pullman et al., 2010; Szolnoki, 2013; Fortis et al., 2016; Pomarici et al., 2015), which boasts 523 PDO and PGI products.

As in other European country, numerous sustainable practices have already been implemented by many firms in the wine industry during the last years, based on voluntary standards, management systems and specific agendas (Mariani and Vastola, 2015; Annunziata et al., 2018; Pullman et al., 2010; Szolnoki, 2013). Compared to other agricultural activities, the wine industry as an evolving economic activity resulted to be very inclined to achieve a rich set of tasks through its specific organizational capacities and resources (Annunziata et al., 2018).

The effects of recent trends in the wine sector are visible on the local landscape (Mariani and Vastola, 2015). Using Corine Land Cover maps, vineyard realities and landscape changes can be observed during three-time periods (2000, 2006 and 2012). The growing hectares for vineyards have been supported by a profitable market, noticeable in many Italian regions (Zhu et al., 2016). The spatial elaboration was implemented through a Geographic Information Systems (GIS) (Voivontas et al., 2001; Zambon et al., 2017a), extracting only the class of vineyards. Specifically, economically relevant areas such as in Tuscany and Veneto regions recorded an increasing cultivated surface area, allowing an improved production of

their typical wines (e.g. Chianti and Prosecco) (Zhu et al., 2016; Brunori and Rossi, 2007).

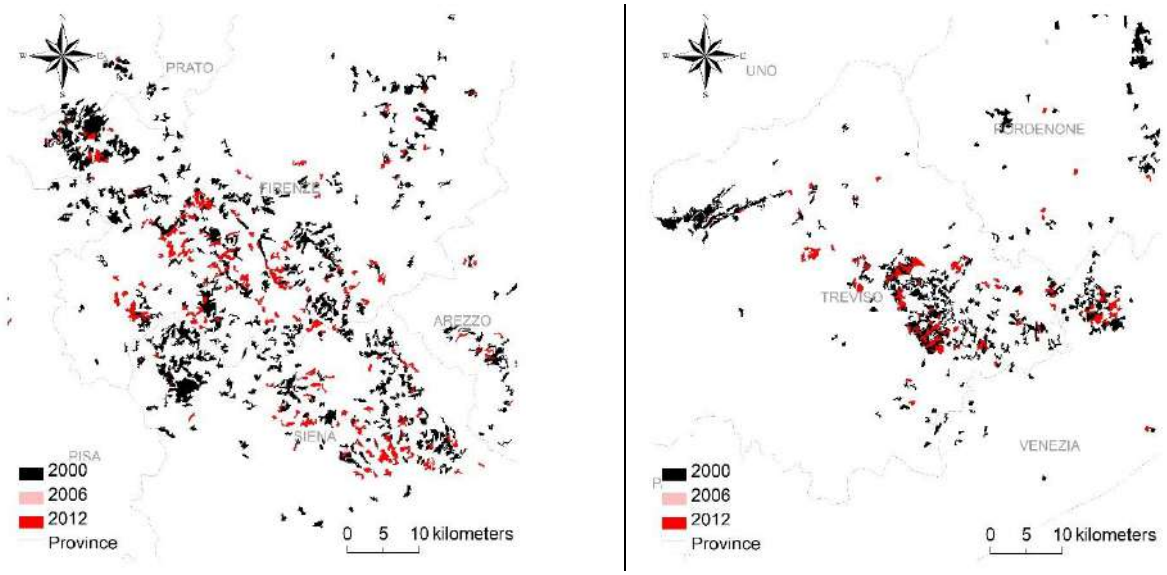


Figure 8.25. Land-use trends concerning vineyards in Tuscany (left) and Veneto regions (right).

8.8.1. Integrating Economy, Landscape and Energy in Local Viticulture Realities

Performing all the operations required for data collection, sixteen Italian vineyards were analyzed. They are in the provinces of Treviso, Pordenone and Udine, in the northern area of Italy. This territorial context was assumed as local case study since it is strongly devoted to the wine production. The examined vineyards cover a surface area of 30 hectares. They were selected according the type of harvesting site and the extension of the plot (width > 1 hectare). Operations were carried out providing a reliable data source on a real working situation. Each vineyard was scheduled according several characteristics (statistics for each firm, relating to the management techniques and/or mechanization processes). A set of specific data identifies each context in analysis such as: the name of the firm; geographical localization (e.g. province, municipality, location, address); the collector as the firm that carried out the collection; and the distance from the transfer center (expressed in kilometers). Time references specify each stage of the process (e.g. date). The structure of each vineyard was described by specifying its surface area (expressed in hectares), spatial position and detailed measurements (e.g. inter-row line and distance between wine rows in meters, number of homogeneous rows). The features on the pruning management were stated according to: year of planting of the vineyard; variety of cultivated wine crops; vineyard breeding system; type of pruning (manual or mechanical); and ratio between the number of rows and that of bands.

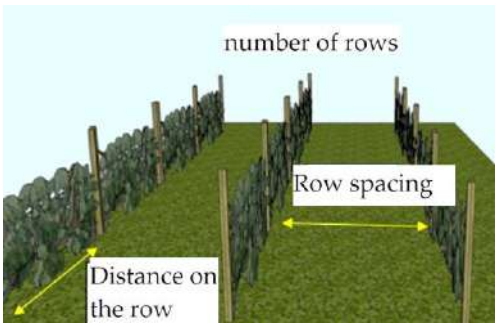


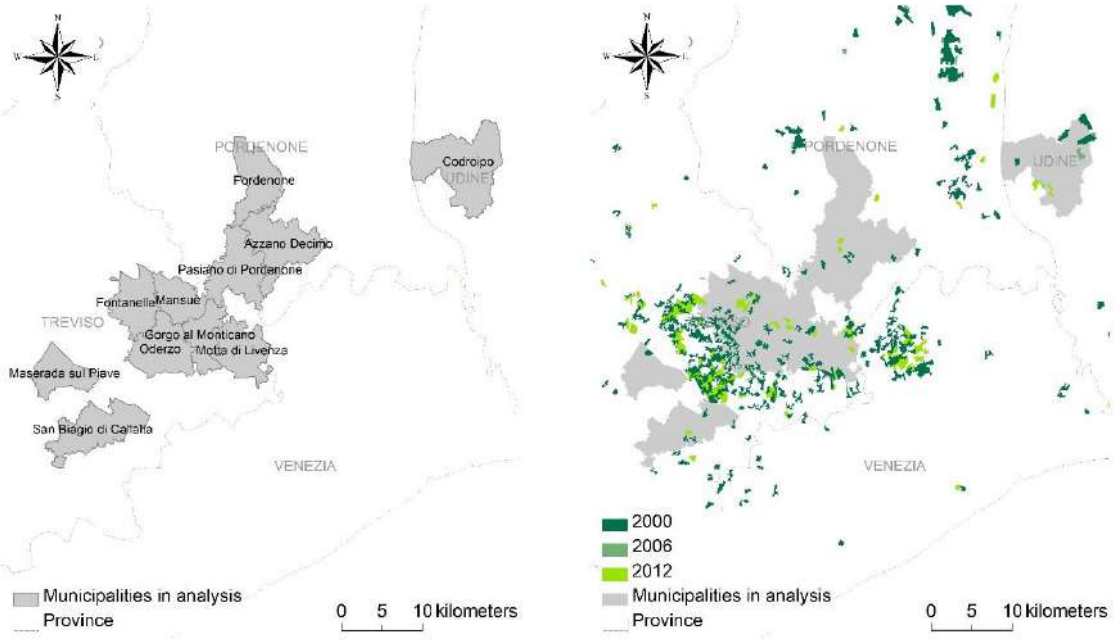
Figure 8.26. Graphic processing of parameters detected in each vineyard.

Field sampling tests essentially involved the collection, the weighing of the resulting pruning material (aimed at estimating the residual biomass production) and the timing collection. An estimation system

(called "grid") was used. The availability of the resulting biomass depends on many factors (Francescato et al., 2007). For weighing operations, a data acquisition method was drawn up, following the UNI EN 14778/2011. This normative directs which methods applied for the preparation of plans and certificates and for the taking samples of solid biofuels (e.g. cultivated areas). After weighing operations, a representative sample was collected and subsequently analyzed in the laboratory. The instrumentation used for sampling tests was variegated, e.g. georeferenced camera, pota scissors, adhesive labels for the classification of samples etc.

Using elaborations maps from Corine Land Cover dataset, vineyard expansion has risen to landscape changes. Due to the profitability of wine production, especially if of high quality, spatial transformations concerned a land conversion towards viticulture uses, leading to a homogenization of the local landscape. This phenomenon occurred in areas owing a consolidate commercial system based on wine, which results to be a chief product for their local economy.

The economic realities analyzed are placed in some municipalities in the Northern Italy given the recent and exponential development of the wine sector in this context. Especially, the work focused on the provinces of Pordenone, Treviso and Udine, which recorded a growing surface area designed for vineyards with positive rates, respectively of 9%, 21% and 23%. As detected in Figure 8.27, a rapid expansion of vineyard-grown areas in 2012 was witnessed in these contexts, where their wine products are even marked with PDO and PGI labels.



(a) (b)

Figure 8.27. Municipalities where are located the economic realities analyzed (a) and the expansion of vineyards over time (2000-2012) (b).

356 homogeneous rows were detected at the local scale, occupying about 4140 meters of wine rows. Furthermore, the distance between the work sites considered and the supply centers for the harvested product was evaluated. Looking for energetic and economic sustenance, an optimal distance from the supply centers was fixed at 30 kilometers. The nearest distances were 1.5 kilometers away; while, the furthest one was 37.5 kilometers.

8.8.2. Energy and mechanization assessment

Results confirmed around 2 tons of biomass / year can be obtained from viniculture activities. A production of about 1,540,000 tons / ha / year (water content of 50%) can be estimated in Italy. Referring to

dry matter, the vine wood has a lower calorific value (19.8 MJ/Kg), higher than spruce (18.8 MJ/Kg) and beech (18.4 MJ/Kg); then, it has an ash content between 3% and 4% with a melting point higher than 1,400°C. Considering the calorific value (water content of 50%), it amounts to 2.4 kWh / kg, producing 3,141,600 MWh / year of thermal energy (energy obtainable from about 273,182 tons of diesel). Assuming an annual activeness of boilers for heating of 1,500 hours, it reaches a total thermal output of 2,094 MW. Producing cogeneration, it could get 628,320,000 kWh of electricity and 2,513,280,000 kWh of thermal energy. The quantity of shoots per hectare fluctuates from 1.7 to 3.9 tons; while, considering the dry weight, it varies from 1.0 to 2.5 tons per hectare (Figure 8.28a). The average water content diverges from 37.3% to 47.6% (Figure 8.28b).

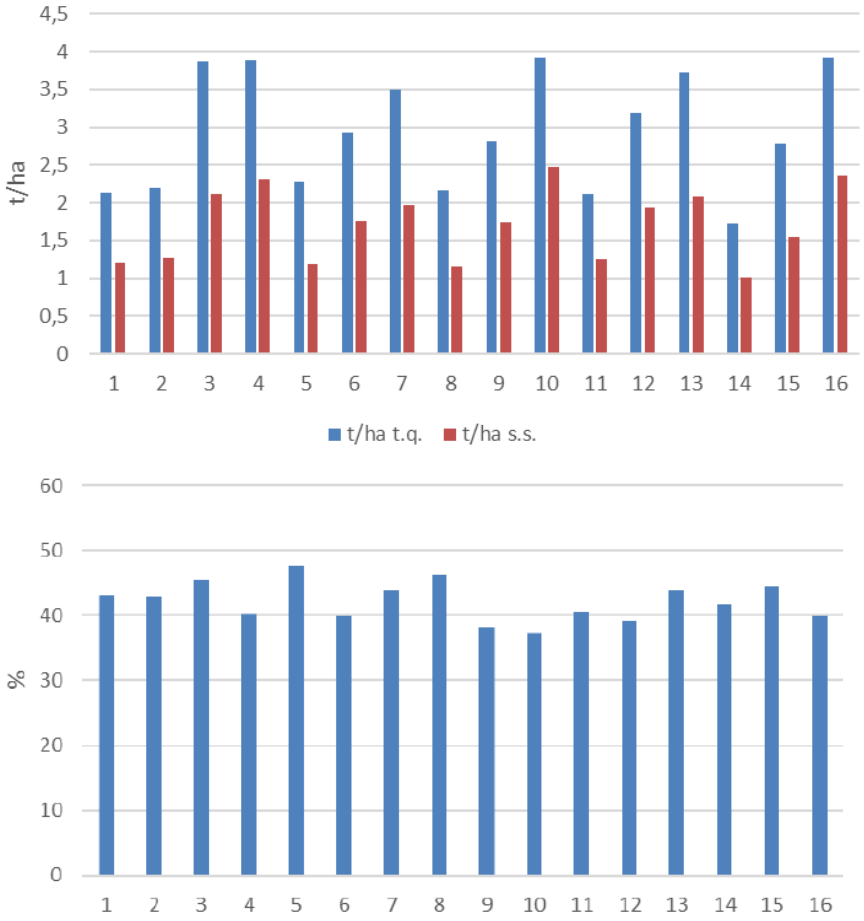


Figure 8.28. Number of shoots on the ground in each case study (a); average water content of shoots in each case study (b).

Evaluating these contexts in energy terms, 4 work sites were analyzed during the biomass harvest: shredding of wine shoots (i) with and(ii) without harvesting; (iii) packing of bales of 1.2 m x 1.5 m; and (iv) packing of bales of 0.6 m x 0.4 m. The work sites all work in commune. A preliminary step allows the turning of wine shoots, usually accumulated in alternate rows, an easier turning maneuver and an optimization, in terms of time, of the subsequent processing.

Excluding the number of shoots per hectare remained on the ground after mechanization processes (0.08 to 0.52 tons per hectare with an average water content from 33.6% to 46.3%), results from gasification test showed that vineyard pellets are a biofuel with homogeneous characteristics. The syngas composition is suitable for motor power supply, where process conditions were stable and highly repeatable. The formation of ash and tar with wine pellets is slightly higher than wood pellets, but not critical. Furthermore, no fusion slag formation was observed in the reactor. The filter must be replaced a bit earlier than normal:

with a used filter the pressure rises to a rate of 5 mbar / h, with a new filter at 1.5 mbar / h (therefore in the standard). The experimental test has therefore had a positive outcome since wine pellet therefore seems potentially usable in micro cogeneration units based on the gasification process.

Assessing energy sustainability exposed that both the production chains of the wood chips and the chains to produce pellets are energy-efficient. The chains with collection sites in small bales and large bales are the (energetically) fewer impacting ones, while the dies with the in-line and parallel forage harvester are slightly more energy-intensive. The comparison with fossil-based diesel also demonstrated the great convenience for the collection and use of wine pruning for energy purposes.

8.8.3. Economic evaluation

To exhaustively evaluate economic advantage to turn out wood chips, pellets and briquettes, four wine's collecting and processing chains were analyzed by packing site in: forage harvester on line (TCL), parallel forage harvester (TCP); large bales (BG); and small bales (BP). The economic data related to the various cost items refer to those in the AIEL database - Italian Society of Agroforestry Energy and other bibliography.

Table 8.16. Cost of different operations of collection and transformation of wine shoots.

Operation	Minimum cost (€ / tons)	Maximum cost (€ / tons)	Water content *
Forage harvester on line	20	30	35
Parallel forage harvester	64.5	64.5	35
Large bales	25	30	35
Small bales	34	40	35
Chipping	25	33	25
Transport	10	15	25-35
Storage, natural drying and handling	7	10	25
Shredding pre-densification	5	10	10
Briquetting with plant amortization	75	85	10
Pelleting with plant amortization	85	110	10

* expressed as a percentage

From the economic analysis of the production chains, the average production cost of wood chips from wine shoots ranges from 46 to 87 € / t. This supply chain is not as much of expensive. The average cost of total production of briquettes has a range between 133.5 and 174.5 € / t. The highest cost derives from the densification operation that normally equals (or even exceeds) the cost of all previous operations. The average total production cost of pellet from agricultural origin falls within a range between 151 and 192 € / tons, resulting the most expensive one. Considering the average costs of products in the hypothetical economic market, which are around 80-110 € / tons for wood chips, 150-180 € / tons for briquettes and 185-220 € / tons for agricultural pellets (all VAT excluded), following the AIEL database, all chains appeared to be economically practicable. Regarding transport costs, a maximum distance of 30 kilometers from the transfer center was assumed. This value can be used as limit of cost-effectiveness of the supply chain. While bales are always transported on an agricultural trailer, pellet chips can be transported on an agricultural trailer towed by a tractor on shredder loading yards. Among additional costs, there is also the manpower of a tractor operator. Finally, the construction sites that are on average less expensive from an economic viewpoint, such as forage harvesters, are the most impacting ones; while, the packing yards, which are more economically demanding, are energetically less expensive.

8.8.4. Rethinking Sustainability with energy

Explaining (and achieving) sustainable development in local contexts, the typical three dimensions (economy, society and environment) may be restricted (Buytaert et al., 2011; Hueting and Reijnders, 2004;

Lélé, 1991; Pope et al., 2004; Najam and Cleveland, 2003). The notion of "sustainability" appears rather limited today since it is integrally normative, complex, subjective and vague (Kasemir et al., 2003). Reflecting on the role of energy (Omer, 2008; Vera and Langlois, 2007), landscape and land-use changes emphasizes an additional intrinsic value meant for sustainability. Additionally, sustainable development requests an acceptable supply of energy resources, available in the long term and at reasonable costs, deprived of undesirable social impacts (Dincer, 2000).

Being the most damaged in recent decades, rural areas require a confident change based on the principles of multifunctionality (Duvernoy et al., 2018; Gobattoni et al., 2015). In the present work, the wine sector has been used as an interesting economic reality in the Italian framework. The conversion of many hectares from abandoned farmland to vineyards has directed toward different land-use changes. The importance of managing territories starting from their land-use destination is essential with the intention of protecting local identity, landscape and biodiversity (Buytaert et al., 2011; Hennenberg et al., 2010; Lee et al., 2008; Schubert et al., 2009). Particularly specific areas, which founded their economy on wine products, have seen a homogenization of their landscapes. This fact often coincided with the presence of wines with PDO and PGI labels, as prosecco wine in Veneto region. Additionally, outcomes confirmed that the increase in the quality of the wine sector has involved the whole Italian country.

The wine sector can also strengthen the local identity and offer job opportunities (Brunori and Rossi, 2007), even in the form of seasonal work. In this context, it would be useful to deepen the role of job market and social influence on an economic reality, such as viniculture (Bailey, 2009; Bailey et al., 2014; Bailey, 2014; Bedford, 2013). Increasing its social and employment backgrounds, a network of actors can be established through local districts that can integrally and spatially perform among different (socioeconomic) realities promoting a larger vision that also embraces the energy dimension (Najam and Cleveland, 2003). Agro-energy chains within specific territorial areas might interrelate and advance synergies, also lowering production costs (Manos et al., 2014). In this regard, using biomass for energy as part of a sustainable development approach is deeply discussed since many concerns emerged about sustainability (Buytaert et al., 2011). Bioenergy systems can be defined as complex systems having an impact on many kinds of scales (e.g. society) (Tenerelli and Monteleone, 2008).

Establishing a spatial system based on circular economy (Zambon et al., 2017a), the benefits of an agro-energy district, compared with conventional systems, appears to integrate different dimensions (economic, society, environment and energy), increasing the denotation of sustainable development (Najam et al., 2003). It may vary based on different crops, regions and technologies employed; particularly, certain damaging processes can be limited (or better avoided) in specific highly-sensitive areas to degradation processes such as soil erosion, also contributing to a real loss of biodiversity (Buytaert et al., 2011; Hennenberg et al., 2010; Pimentel et al., 1995; Pimentel et al., 2005; Fami et al., 2010).

Agro-energy planning needs a complex investigation based on an integrated analysis of the local availability of biomass resources and the environmental impact of energy crops (Tenerelli and Monteleone, 2008; Torquati et al., 2014). In this perspective, the present work also focused on energy and environmental viewpoint. Several studies have progressively assessed the combustion of pruning shears at different scales, confirming the environmental (and even energetic) sustainability of wine biomass (Yazan et al., 2011; Santiago-Brown et al., 2015). The evaluation of the quality of atmospheric emissions from the combustion of pruning plants can confirm the degree of sustainability obtained from the combustion of biomasses. However, it is necessary to investigate this issue in greater depth to optimize the combustion methods of possible thermal plants and to ensure both a safe energy process and an emission level compatible with current regulations.

Furthermore, also new technologies can assist to assess agro-energy districts (Tenerelli and

Monteleone, 2008). Multicriteria methods through Geographic Information Systems (GIS) are mainly suitable for both the spatial analysis of biomass supply systems and decision support in the bioenergy sector (Voivontas et al., 2001; Zambon et al., 2017a, d; Malczewski, 1999; Mitchell, 2000; Noon and Daly 1996; Overend and Mitchell, 2000). Sustainability has turn out to be a crucial matter for the wine industry (Corbo et al., 2014) since the amounts of wine residues produced annually have grown up in Italy. Following the existing literature, over 4 tons of biomass / year can be obtained from viniculture activities (Barella et al., 2010). However, the results obtained confirmed that data around 2 tons / hectare / year are more reliable. From its pruning practices, a biomass production can be estimated equal to an average of 1.5-2.5 tons / hectare / year (water content of 50%). The results obtained recognized that the quantity of shoots per hectare fluctuates from 1.7 to 3.9 tons; while, considering the dry weight, it varies from 1.0 to 2.5 tons per hectare. The average water content diverges from 37.3% to 47.6%. This variability in the production of residues is linked to many factors, such as structure, geographical location and position of the vineyard (Francescato et al., 2007).

From the economic investigation, different scenarios can be depicted. However, the reuse of rural residues brings about the cheapest strategy for a local sustainable development as wood chips from wine shoots ranges from 46 to 87 € / tons. By integrating the four dimensions (energy, economy, society and environment) that can lead to greater sustainable development, agro-energy districts applied to realities such as the wine-producing ones may be an emergent phenomenon that provides a new scenario of rural areas in the evolution towards a sustainable (energy) future. But the present research suggests that further development of policies, strategies and network of local actors must be structured and well managed is essential to accomplish long-term positive consequences.

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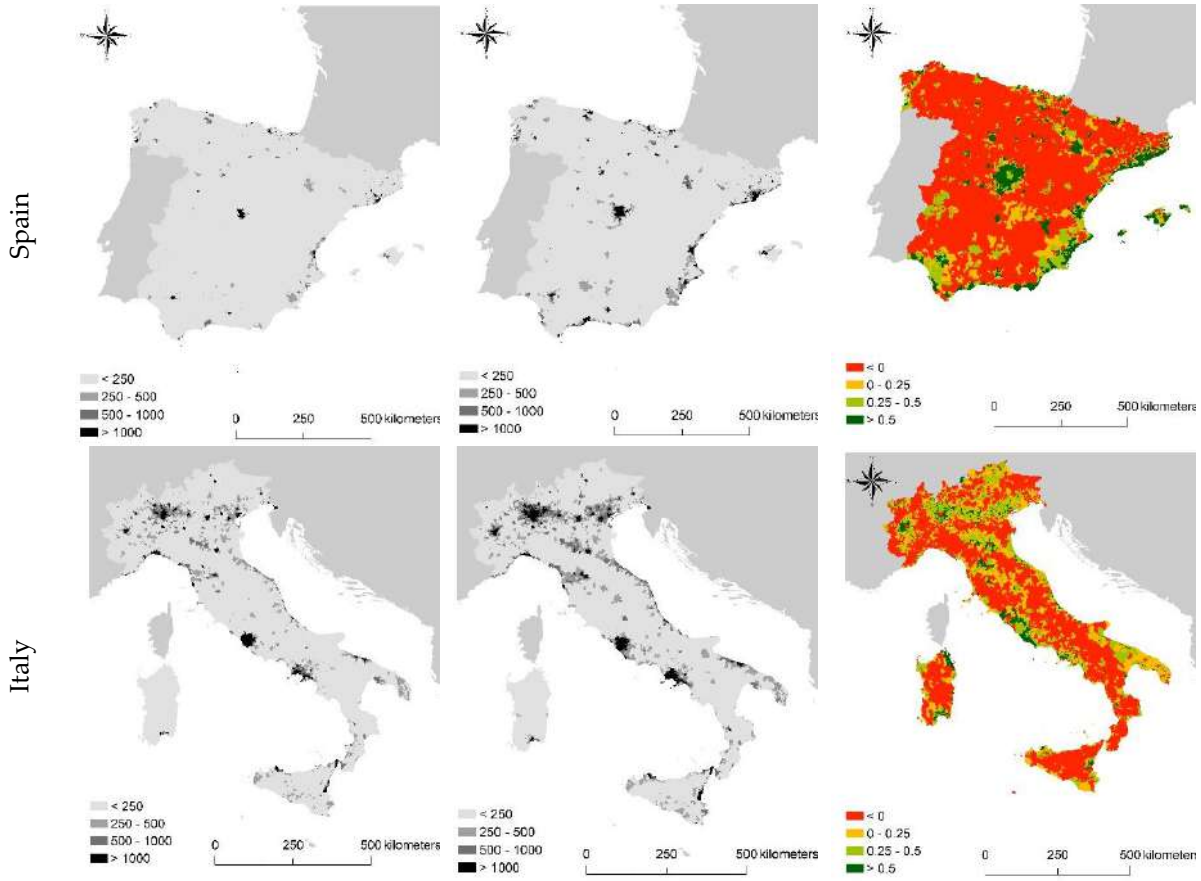
9. Unpublished works

9.1. A local-scale analysis of population dynamics in Mediterranean Europe, 1961-2011

Different socioeconomic, historical, political and cultural factors have influenced long-term settlement patterns and demographic structures in Europe. Southern Europe is considered a relatively homogeneous region as far as settlement characteristics and population dynamics are concerned. Within-country local variability in the spatial distribution of population is high, and evident differences across countries may outline dissimilarities in demographic patterns. A comparative population analysis including five countries over a relatively long time period (1961-2011) contributes to identify latent demographic trends in Mediterranean Europe at the spatial scale of Local Administrative Units (LAU). Basic indicators of population density and demographic changes allow identification of territorial disparities, reflecting local-scale patterns common to different countries (e.g. coastalization) and contributing to consolidate a metropolitan hierarchy at European scale. At the same time, the examined countries present different territorial contexts resulting in distinct population dynamics in turn influenced by internal (e.g. national policies, culture and local identity) and exogenous (e.g. economic cycle, urbanization models) factors. A spatially-explicit analysis of demographic trends at local scale may contribute to rethink urban strategies and spatial planning adapting to heterogeneous and rapidly-changing socioeconomic contexts across Europe.



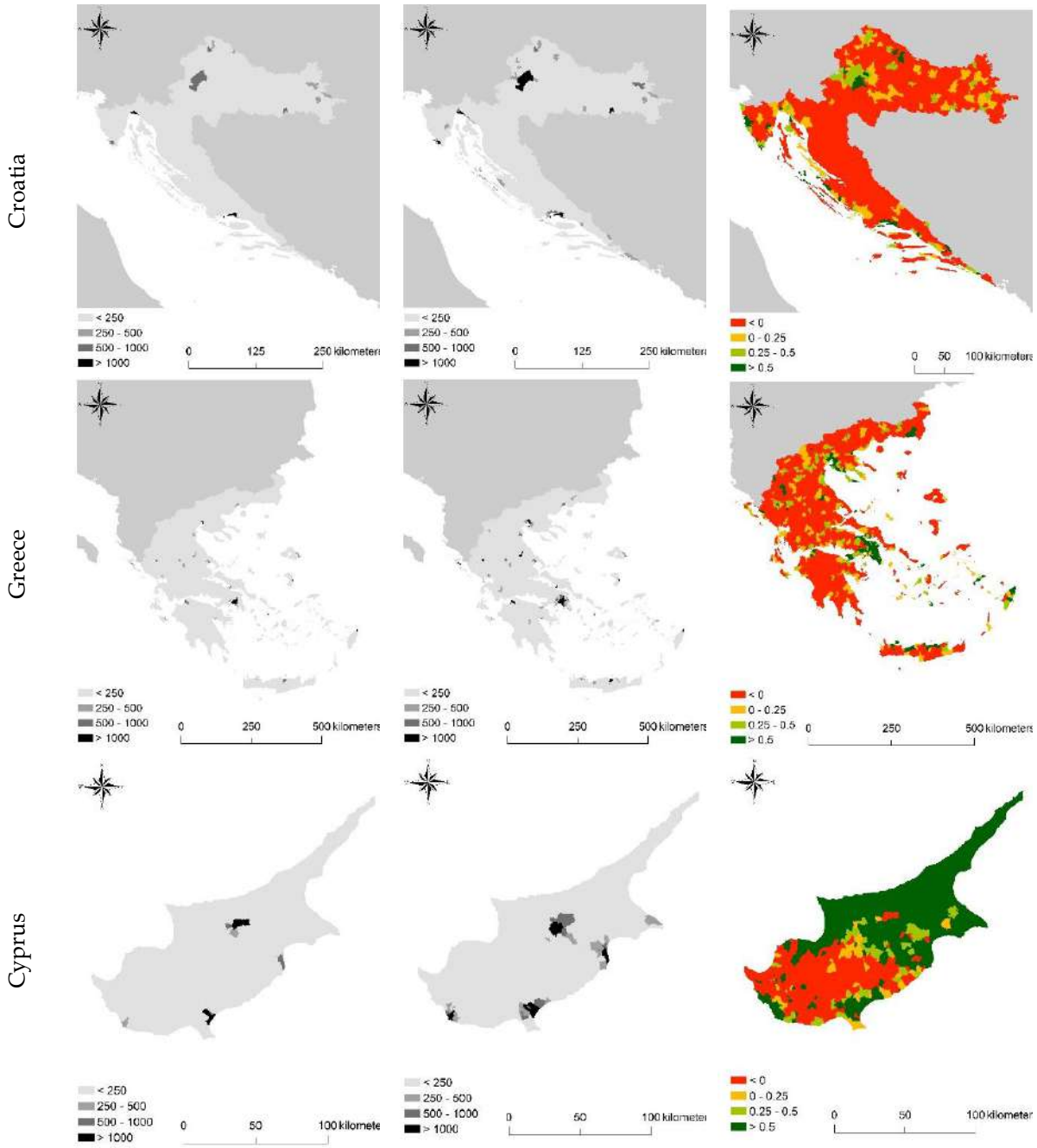


Figure 9.1. Population density (inhabitants / hectare) in 1961 (left), 2011 (middle) and per cent annual rate of population growth in 1961-2011 (right).

9.2. Agglomeration Economies, Industrial Structure and Related Variety: A Reflection Based on a Metropolitan Case Study

The notion of socioeconomic resilience assumes a key role when assessing the impact of economic shocks on production structures, demographic dynamics, urbanization and social stratification processes. Various approaches have been proposed to estimate socioeconomic resilience; one of the most common techniques focuses on the degree of diversification of production structures characterizing homogeneous economic systems, for instance at regional scale. This contribution formulates a reflection in the issue of economic resilience of regional systems, adopting the metropolitan region of Athens (Greece) as a case study. For this purpose, an Evenness Index was proposed to quantifying heterogeneity of the production system in the study area taken as a measure

of resilience over a short-term (2002-2008) encompassing a phase of economic expansion driven by the 2004 Olympics. Based on the resulting findings, the evolution of the metropolitan production structure - examined in combination with urbanization processes and recent dynamics of income and wealth (e.g. related to the 2007 crisis) - provides a meaningful assessment of the degree of resilience in a given area. Understanding spatio-temporal patterns of economic resilience can support adoption of explicit developmental policies addressing specificities and local weaknesses of regional contexts.

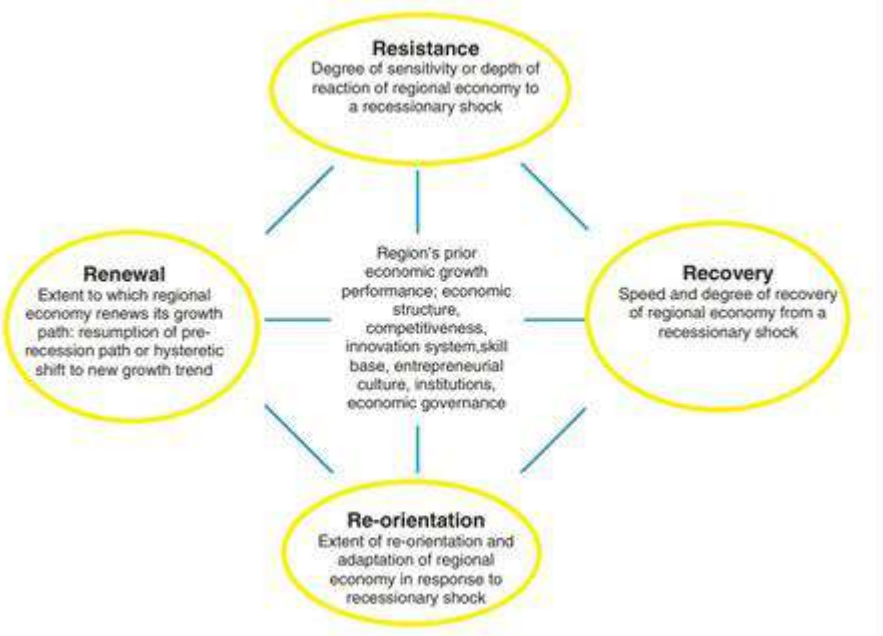


Figure 9.2. Four dimensions of regional economic resilience.

9.3. Back to the (Metropolitan) City: Revisiting Long-term Population Dynamics and Urbanization Patterns in Europe, 1950-2000

Spatially-varying patterns of population growth reflect different development trajectories at both urban and metropolitan scales, following distinct trends towards urbanization, suburbanization and re-urbanization. A comparative analysis of long-term urban cycles based on wide-ranging population dynamics, with identification of the most relevant factors of growth and change, is still missing for European cities. The purpose of this work is to investigate spatio-temporal patterns of population growth in 174 European metropolitan regions contrasting demographic dynamics observed in inner cities and ring areas and identifying metropolitan clusters associated with specific background socioeconomic contexts. A mixed (parametric/non-parametric) statistical approach was developed to assess spatially-explicit patterns of population expansion in inner cities and ring areas, inferring in this way the socioeconomic context underlying urban (and metropolitan) growth and decline in 5 European macro-regions and 17 countries. Investigating population dynamics over a 50-years pre-crisis urban cycle (1950-2000), allows detecting similarities and differences in urbanization patterns and processes across Europe, contributing to a more complete understanding of growth factors that reflect the increasing polarization between core cities, ring districts and the neighbouring rural areas. Based on the uniqueness in metropolitan population dynamics, this study aims to bring insights on the debate over the future development of European cities.

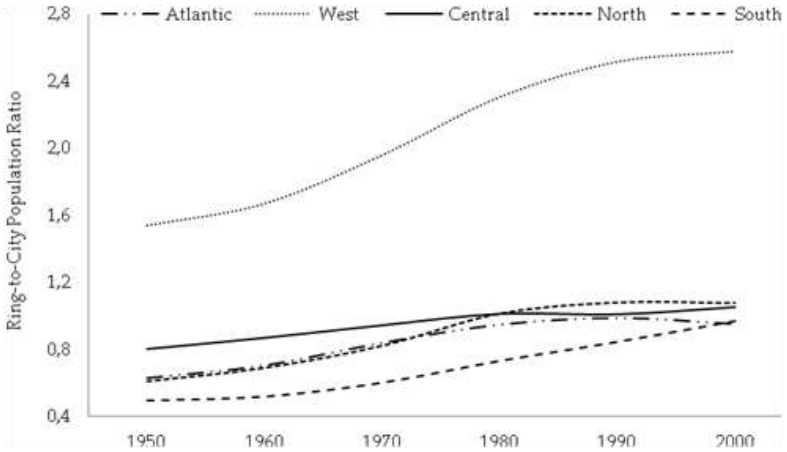


Figure 9.3. Ring-to-City population ratio in European macro-regions, 1950-2000.

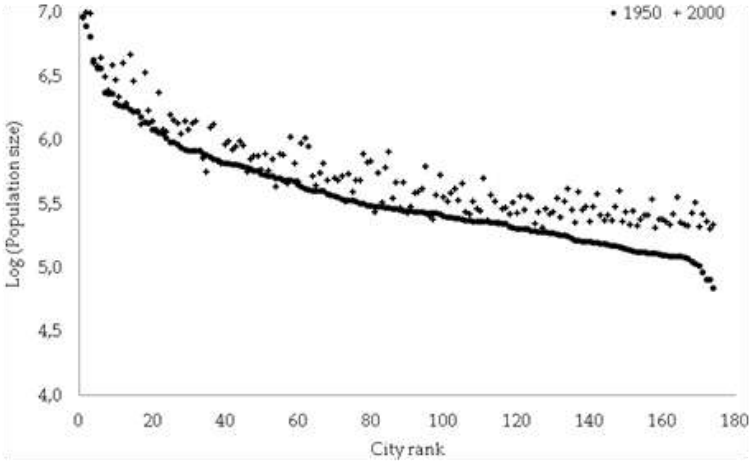


Figure 9.4. Rank-size plot for European metropolitan regions, 1950 and 2000.

9.4. Metropolitan Growth and Urban Cycles in a Mediterranean Country, 1910s-2010s

Long-term urbanization trends worldwide reflect important socioeconomic transformations at the metropolitan scale, being also increasingly dependent on place-specific processes of change. By investigating vertical profile and age of buildings over one century, the present study identifies sequential urban cycles in Greece and characterizes the dominant socioeconomic profile at local scale over 12-time intervals between mid-1910s and mid-2010s. Our results outline a spatially-complex expansion path associated with different urban waves (dense urban growth, hyper-densification of inner cities, semi-dense suburbanization of fringe districts, sprawl in coastal and more accessible internal rural areas), indicating that the Greek metropolitan system underwent rapid transformations over economic expansions and recession. Distinct spatial patterns in building activity characterized Greek municipalities, reflecting geographical gradients (urban-rural divides, coastal-inland polarizations) and divergent responses to market stimuli and planning constraints. A local-scale analysis of urban cycles grounded on indicators derived from official statistics and covering a relatively long time period may shed light in latent patterns of cities' growth and change, clarifying the contribution of housing and real estate markets to an integrated strategy for sustainable development of metropolitan systems.

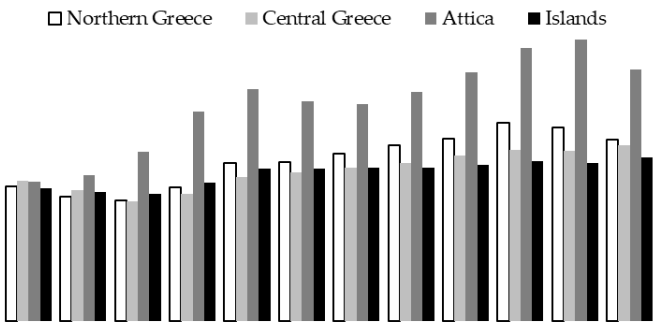
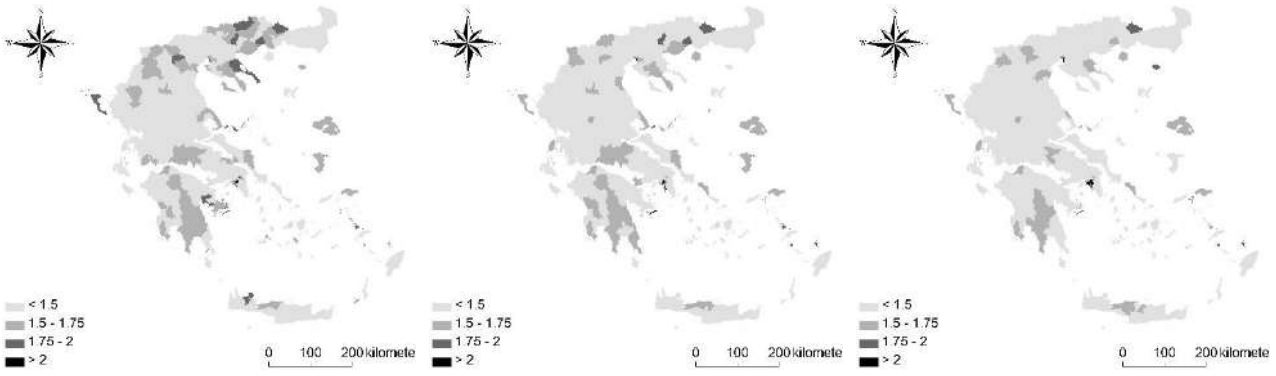
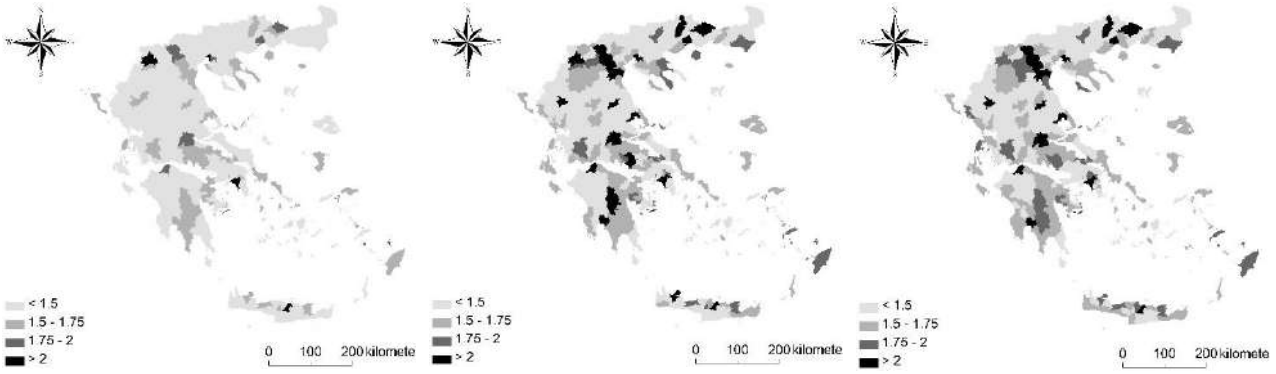


Figure 9.5. Average number of floors per building by time period and macro-region in Greece.



< 1919 1919-1945 1946-1960



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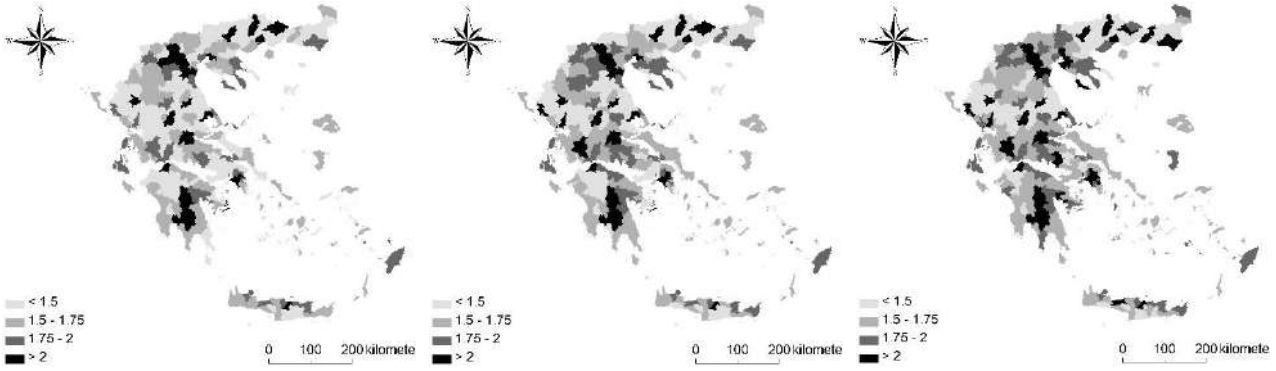

1986-1990 1991-1995 1996-2000

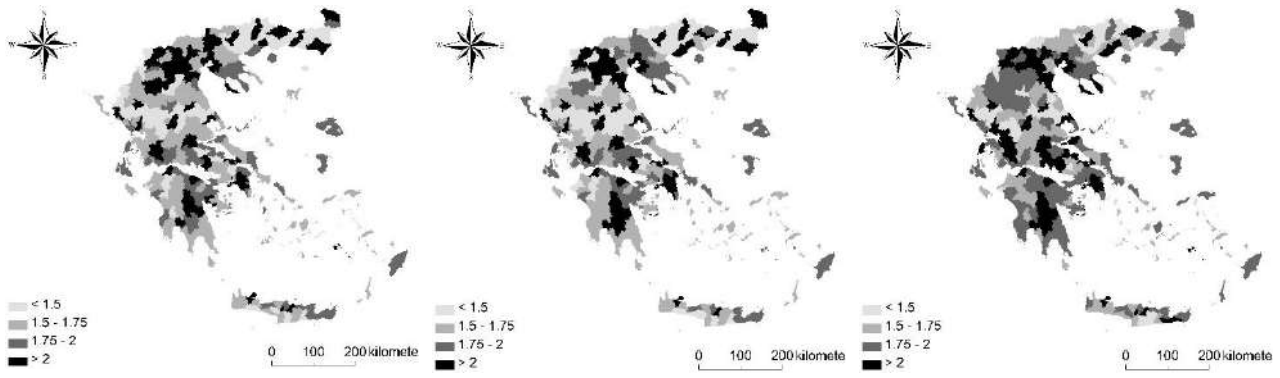

Figure 9.6. Average number of floors per building in Greek municipalities by time period.

9.5. The Long Breadth of Cities: Revisiting Worldwide Urbanization Patterns, 1950-2030

By Margherita Carlucci, Carlotta Ferrara, Kostas Rontos, Ilaria Zambon, Luca Salvati

A comparative analysis of population dynamics worldwide contributes to profile distinctive demographic and economic trajectories of urban growth, discriminating processes of settlement concentration or dispersion under sequential cycles of urbanization. However, a wide-ranging characterization of urban cycles based on demographic dynamics worldwide is still missing. The present work is aimed at filling such a gap analysing long-term changes (1950-2030) in annual population growth rate of 1691 urban agglomerations with more than 300,000 inhabitants in 74 world countries. Results of this study indicate that metropolitan growth worldwide was associated with largely variable rates of population growth, highly positive before 2000 and progressively reducing over recent decades. Despite important differences at continental (and country) scale, demographic expansion of urban agglomerations showed two contrasting phases with a break point in the 1980s denoting a progressive reduction in spatial heterogeneity of population growth rates and a moderate slowdown in demographic dynamics. Intensity of urban expansion and spatial heterogeneity in population growth rates across metropolitan agglomerations evidence a trade-off between fast and slow demographic dynamics. These findings can be better understood to support theories of sequential city growth, making a suitable contribution to policy making, especially in countries where urban population is expanding more rapidly

Table 9.1. Mean annual rate of population growth (%) by selected temporal period and country.

Country	1950-1955	1970-1975	1990-1995	2010-2015	2025-2030
Argentina	0.69	0.61	0.36	0.27	0.21
Australia	0.81	0.67	0.42	0.31	0.26
Brazil	1.23	1.10	0.57	0.33	0.20
Canada	0.80	0.40	0.29	0.23	0.20
China	1.13	1.03	1.52	0.61	0.27
Egypt	0.78	0.39	0.35	0.32	0.43
France	0.23	0.25	0.12	0.10	0.17
Germany	0.36	-0.04	0.02	0.08	0.07
India	0.77	0.81	0.61	0.54	0.46
Japan	0.76	0.58	0.16	0.09	0.01
Russian Federation	0.74	0.58	0.00	0.05	-0.01
South Africa	0.74	0.66	0.72	0.51	0.26
United Kingdom	0.09	-0.08	0.06	0.13	0.18

United States of America	0.76	0.49	0.59	0.34	0.21

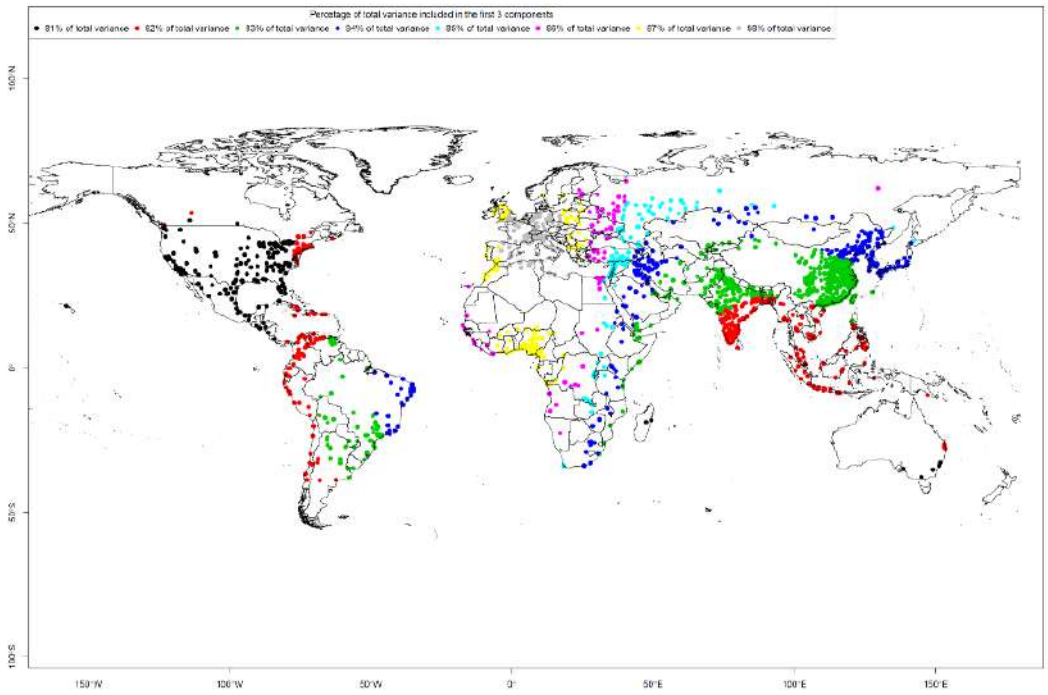

Figure 9.7. Percentage of total variance included in the first 3 components.

9.6. Demographic Dynamics, Urban-rural Transition, and the (Changing) Mother's Age at Birth in Greece: A Regional Analysis, 1980-2016

Being more sensitive to economic fluctuations, childbearing postponement increased during the second demographic transition and was accompanied by a moderate decline in the number of children per woman and the progressive rise of mother's age at the first birth. Under the hypothesis that recessions have a marked influence on population dynamics, the present study investigates spatial changes in mother's age at birth in Greece with the aim to assess the differential impact of economic crisis along the urban-rural gradient. The percent composition of births by mother's age class - considered a gross indicator of fertility under a changing socioeconomic context - was studied at 4 spatial scales (the whole country, administrative regions, prefectures and metropolitan areas or specific economic districts) over an economic cycle (1980-2016) from expansion to recession. While alimenting a process of childbearing postponement observed since the early 1980s, empirical results of this study indicate that the 2007 recession was quite neutral on fertility trends in Greece, consolidating the traditional divide between urban and rural areas.

9.7. Diversification in Urban Functions as a Measure of Metropolitan Complexity

In elaboration.

9.8. Residential vs industrial development in the Valencian Region in the contemporary years

In elaboration.

9.9. Recession Matters? Local Labor Markets and Regional Unemployment Divides in Italy, 2004-2013

Economic cycles in wealthier countries have resulted in a progressive transformation of regional spatial structures, possibly strengthening socioeconomic disparities and polarization in the

production base. Local job markets are particularly sensitive to changes in economic functions, increased regional divides and stagnant product dynamics. The regional spatial structure of unemployment was hypothesized to be strongly affected by economic cycles. To verify this hypothesis, the present work investigates spatial structure and short-term changes of activity and unemployment rate in 686 local labour markets during three phases of the recent economic cycle in Italy: (i) employment growth corresponding to moderate economic expansion (2004-2007); (ii) early crisis' stage with moderate increase of unemployment (2007-2010); and (iii) late crisis' stage with marked increase of unemployment (2010-2013). The empirical analysis identified the socioeconomic factors better characterizing labour market dynamics. Results pointed out that the 2007 recession has corresponded to decreased spatial polarizations in unemployment rate, reflecting an attenuation of the traditional gap between affluent northern regions and disadvantaged southern areas.

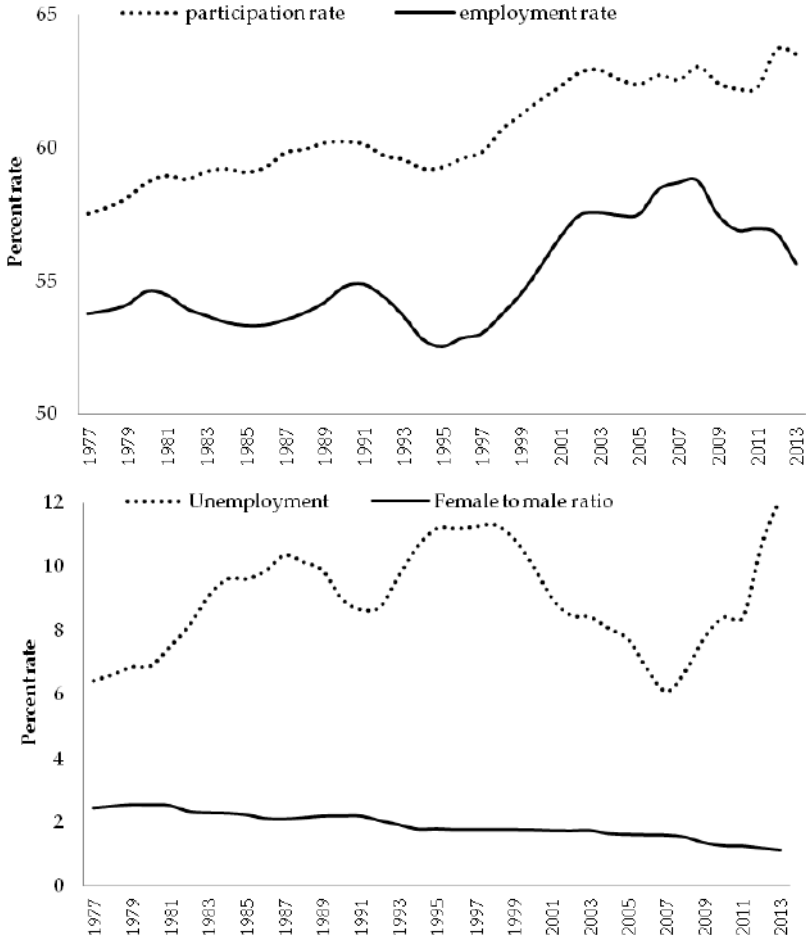

Figure 9.8. Job market indicators in Italy, 1977-2013.

9.10. Mediterranean desertification and local communities' permanent assessment and implications for mitigation policies

The international definition of the United Nations Convention to Combat Desertification indicates 'land degradation' as a 'reduction or loss of the biological and economic productivity' resulting from land use mismanagement, or a combination of processes, such as soil erosion, deterioration of soil properties, and long-term loss of natural vegetation. Land degradation (LD) is hence an interactive process involving multiple factors, among which climate, land-use, economic dynamics and socio-demographic pressure play a key role. Particularly in the Mediterranean region,

joint biophysical and socioeconomic forces are the main factors shaping vulnerability of both natural and agricultural land, and their interaction may become extremely complex over time and space, resulting in specific patterns of land degradation. To identify and quantify the local distribution of vulnerable areas, understanding spatio-temporal trends of LD (together with the actual vulnerability status and the underlying background context) represents a key issue from both positive and normative perspectives. Repeated assessment over time may have practical effectiveness, providing useful tools that inform conservation policies through (i) identification of target areas needing specific actions for biodiversity and landscape protection, and (ii) dynamic evaluation of LD processes in the perspective of global change.

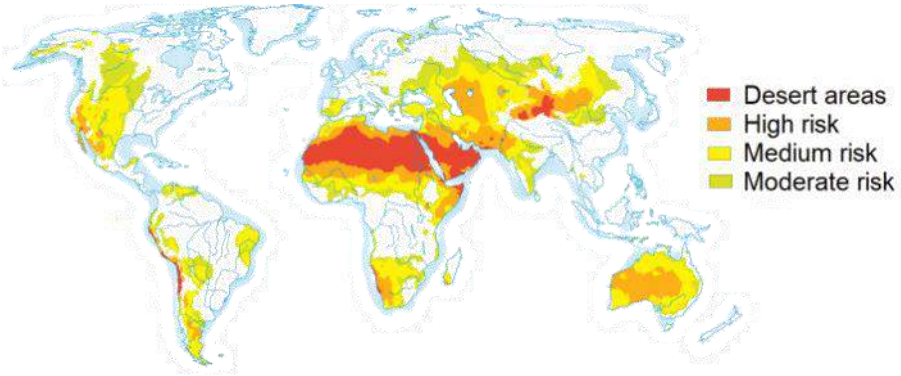

Figure 9.9. Areas in the world with their own state or risk of desertification.

9.11. Population Dynamics, Agglomeration Economies and Municipal Size: A Long-term Analysis

Under the hypothesis that modifications in municipal boundaries and creation (or suppression) of new administrative units reflect a progressive adjustment toward a more balanced distribution of population over space, the present study investigates the long-term relationship (1928-2012) between urban expansion, population dynamics and municipal area in a growing metropolitan region (Athens, Greece). In expanding regions, municipal size is a key variable outlining amount and spatial concentration of services and infrastructures, resulting to be functionally related with population density, agglomeration factors, land availability to building and characteristic socioeconomic profiles of local communities. A statistical analysis of the relationship between population density and municipal area provides basic knowledge to policy and planning adjustments toward a more balanced spatial distribution of population and land among local government units. Descriptive statistics, mapping, correlation analysis and linear regressions were used to assess the evolution of such relationship over a sufficiently long time period. Average municipal area in Athens decreased moderately over time with a slight increase in spatial heterogeneity. Conversely, average population density per municipality increased more rapidly with a considerable reduction in spatial heterogeneity. The observed goodness-of-fit of the linear relationship between population density and municipal area increased significantly over time. Empirical results of our study indicate that municipal size has progressively adjusted to population density across metropolitan areas, determining a more balanced spatial distribution of resident population, which was consolidated by the recent administrative reform of local authorities in Greece (the so called 'Kallikratis' law). Such conditions represent a base for informed analysis of the spatial structure of local administrative units and contribute to the debate on optimal size of municipalities and other administrative districts with relevant impact on both urban and metropolitan scales of governance.

9.12. Recent urbanization trends in a European country: the Italian case

Significant transformations have characterized the Italian economy and society after World War II with important implications for regional organizations and changes in land-use and mainly due to discontinuous expansion of human settlements. Land consumption, linked to the massive use or alteration of agricultural or natural land for settlement purposes, is a measure of soil sealing; over time, soil resources have progressively lost their value as a productive substrate, reducing to 'available space' for building. In this regard, the present paper aims to explore recent urbanization trends in Italy. Land consumption has affected the whole country including - but not limited to - rapidly-evolving large metropolitan areas. New spatial polarities in land-take correspond to a geographical fragmentation of peri-urban landscapes, resulted from spatially-implicit development trajectories and sometimes lacking territorial coordination. Our results also indicate a relatively high land-take rate in agricultural and natural areas. Suitable tools for multi-scale land-use planning, promoting adoption of appropriate, trans-disciplinary strategies managing a fragile territory such as the Mediterranean one.

9.13. Socioeconomic Development and Demographic Transitions in Italy, 1862-2009 a Brief Overview

By Luca Salvati, Margherita Carlucci, Pere Serra and Ilaria Zambon

The present study investigates long-term population dynamics in Italy, 1862-2009, within the theory of demographic transitions. Under the assumption that demographic transitions are multidimensional processes of change involving several aspects involving population structure and dynamics, an exploratory analysis was carried out in this study to verify temporal coherency of 15 indicators over time, identifying homogeneous time periods with distinct demographic characteristics. Indicators' trends were identified using a multivariate statistical approach. Results of this study allows empirical testing of the assumption of temporal coherence between different aspects of a long-term demographic transition in Italy, distinguishing distinctive population dynamics and the differential impact on population structure over two centuries. After a relatively long period of demographic stability, the time window encompassing the two World Wars, approximately between 1921 and 1951, was identified as a primary turning point of population dynamics in Italy; a second turning point was estimated at the beginning of the 1970s. These time intervals represent conditions of dynamic equilibrium between demographic and socioeconomic contexts highlighting latent system transitions. The study concludes outlining the importance of a more effective integration of demographic transition theories into a broader sustainability framework, implementing a diachronic analysis of political, economic, and social forces associated with population dynamics in both advanced economies and emerging countries.

9.14. Spatial Patterns of Population Mobility and the Socioeconomic Context Contrasting Long-term and Short-term Trends in Greece

In elaboration.

9.15. Sprawl Matters the Evolution of Fringe Land, Natural Amenities

In elaboration.

9.16. The (Evolving) Urban Footprint under Sequential Building Cycles and Changing Socio-demographic Contexts

By Ilaria Zambon, Silvia Pili, Pere Serra and Luca Salvati

Total and per-capita urbanization rates are increasingly divergent worldwide, indicating an accelerated land consumption and an increased ecological footprint of cities. Under the hypothesis that spatio-temporal divides in total and per-capita urbanization rates are representative of the evolving urban footprint, this study proposed a multivariate analysis of land consumption spatial patterns in a southern European city (Athens, Greece) throughout a building cycle (1948-2015) reflecting sequential waves of economic expansion and stagnation. The footprint's spatial structure was investigated along the urban gradient using descriptive statistics, mapping, multivariate techniques and inferential approaches. The increase of total and per-capita built-up area over time followed a non-linear trend because of distinct growth waves. Socioeconomic profiles of municipalities with diverging (total and per-capita) urbanization rates changed over the study period because of joint transformations in metropolitan form and functions. Population aging, land-use diversification, vertical profile of buildings and a viable agricultural sector were associated to a low divergence between total and per-capita urbanization rates. Results of our study indicate that more effective policies for sustainable management of peri-urban land may incorporate urban containment strategies based on specific measures: (i) supporting settlement densification, (ii) stimulating brownfield recovery and (iii) concentrating new development in already fragmented, low-quality land, taking account of the background socioeconomic context and the demographic structure of local communities.

9.17. Housing and the City: A Spatial analysis of Residential Building Activity and the Socio-demographic Background in a Mediterranean City, 1990-2017

By Massimo Cecchini, Ilaria Zambon and Luca Salvati

Fluctuations in residential building activity are becoming progressively more intense over time and space in advanced economies - and especially in Europe -, fueling real estate market segmentation and making performances of construction industry increasingly unpredictable. Assuming that non-linear urbanization paths are the result of economic downturns consolidating progressively more volatile real estate markets, the present study investigates the impact of recent building cycles on long-term urban expansion in a Mediterranean city (Athens, Greece), using multiple clustering techniques run on a large set of building activity and socio-demographic indicators. Changes over time in building activity were evaluated considering 12 spatially-explicit indicators derived from the analysis of building permits released by Greek municipalities between 1990 and 2017. By referring to different analysis' scales (macro-scale: settlements, meso-scale: buildings, micro-scale: dwellings), indicators allow a comprehensive investigation of multiple dimensions and characteristics of construction markets at four-time intervals of 7 years each (1990-1996, 1997-2003, 2004-2010, 2011-2017). Spatio-temporal variability in building activity was further investigated considering 12 contextual indicators assessing basic socio-demographic attributes of local municipalities. Cluster analysis allows identification of distinctive, local-scale responses of real estate markets to economic cycles (expansion-stagnation-recession) in both short- and long-term horizons and relate them to the dominant socio-demographic context. Density of new buildings, average floors per new building, density of buildings' additions and number of building permits per

inhabitant were found to be the most sensitive indicators to economic downturns in the study area. Infrastructure-driven development, as a result of the 2004 Olympic Games, has produced relevant short-term alterations in residential construction markets, complexifying urbanization trends at the local scale. Multi-scale indicators from building permit records provide a useful insight in the diachronic mechanisms of urban growth, with implications for regional planning and design of sustainable development practices.

9.18. Unraveling Latent Transformations in Metropolitan Structures: A Local-scale Analysis of Urban Landscapes and Social Functions

Urban growth has been considered an intriguing socioeconomic issue worldwide. Metropolitan expansion in the last decades often resulted in scattered, low-density settlements, occupying semi-natural areas devoted to agriculture and forestry. This process has progressively led to landscape configurations influenced by different socioeconomic, demographic, cultural, political and environmental factors. New challenges including landscape fragmentation, habitat loss, soil degradation and biodiversity reduction emerge from this background context. Rethinking complex dynamics in contemporary landscapes is especially required in socioeconomic contexts characterized by weak planning systems and limited participation to political decisions on land-use. While investigating patterns and processes of urban expansion is increasingly difficult due to social fragmentation and economic polarization of metropolitan regions, there is a lack of comparable statistical information among different metropolitan areas. Based on these premises, the aim of this study is to provide a logical framework to explore micro-scale structures of urban and peri-urban landscapes based on a spatial analysis based on Geographic Information Systems (GIS) tools. This approach was applied to a comparative, micro-scale analysis of landscape structures in three Southern European metropolitan areas (Barcelona, Rome and Athens) with different socioeconomic background contexts. Results of this paper shed light on the intrinsic linkage between landscape structure and social functions, providing an informed knowledge of land-use transformations in contemporary cities.

9.19. Urbanization, Industrial Development and Environmental Externalities. Discussing the Impact of Economic Cycles on a Local Community

A new relationship among urbanization, industrial development and economic externalities has emerged in the last decades, shading progressively the role of urban-rural gradients in regional studies. Addressing complex realities and increasingly debated regional issues, bio-regional approaches have acquired a strong interest in recent years. The present study focused on a case study in Greece (Thriasio Plain) representative of complex socio-ecological systems with a long industrial tradition and transforming relationships between urban and rural areas. Thriasio Plain has been characterized by spontaneous development of various economic activities with increasing impact on a fragile environment dominated by Mediterranean-type vegetation, poor soils and arid climate. Industrialization of the area and the related land-use changes were realized through a sequence of official revisions of zoning plans. By defining a consistent set of indicators (Ecosystems and Air Quality Stress Indices), the present work aims at investigating recent environmental dynamics typical of Mediterranean agro-urban outskirts, discussing suitable practices and projects for a bioregional recovery of degraded areas.

9.20. Changes in Local-scale Climate regime as an indicator of Urban Sprawl - a Time series analysis comparing trends in urban and peri-urban Rome, Italy

By Luca Salvati, Ilaria Zambon, Andrea Colantoni, Luigi Perini, Giorgio Pontuale and Massimo Cecchini

Identifying signals of climate change and increased meteorological variability requires analytical tools aimed at exploring time series data of multidimensional measures. By focusing on air temperature and precipitation regimes, the present study compares local-scale climate regimes in urban and peri-urban Rome (central Italy) using descriptive and inferential statistics on both original variables and a drought index (the Standardized Precipitation Index, hereafter SPI) recorded over the last 60 years (1958-2017). The quantitative analysis developed in this work tries to illustrate two coexisting trends in climate regime: a general trend toward warming and a more specific pattern evidencing changes in local-scale climate regimes along the urban gradient. Empirical results indicate that climate variability increased over the study period, outlining the low predictability of dry spells typical of Mediterranean climate especially in the drier season (spring/summer). On average, absolute annual differences between the two sites amounted to 70 mm (more rainfall in the peri-urban site) and 0.9°C (higher temperature in the urban site). A similar trend toward warming was observed for air temperature in both sites. No significant trends were observed for annual and seasonal rainfalls. SPI indicated high variability in drought periods, with more frequent and severe episodes in urban than peri-urban Rome. Considering together trends in temperature and precipitation, the 'urban heat' effect was more evident, indicating a clearer trend over time toward climate aridity in urban Rome than in peri-urban Rome. These findings encourage the adoption of integrated strategies for climate change adaptation and mitigation of relict natural ecosystems and agricultural systems surrounding urban areas that are expanding rapidly into rural land.

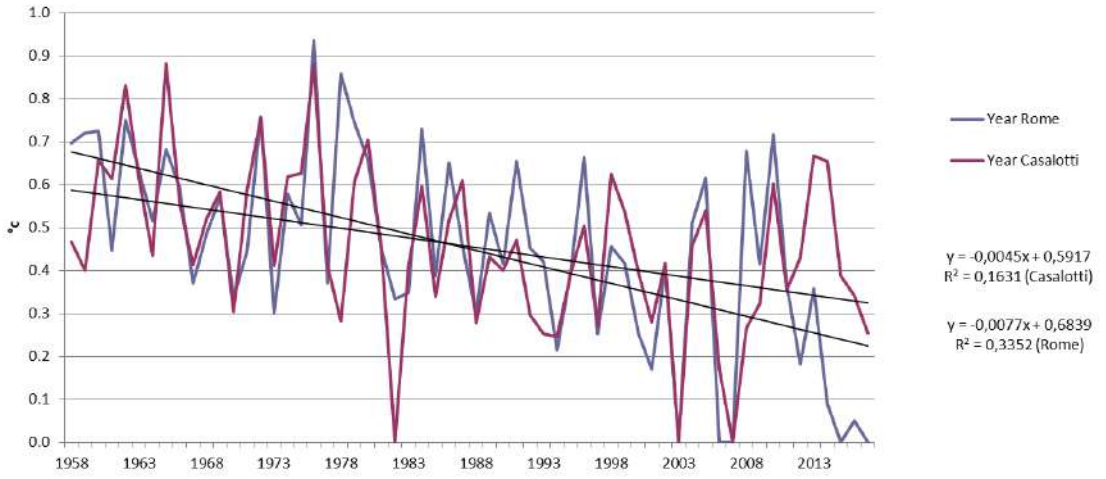

Figure 9.10. Trends over time in a composite index of climate aridity incorporating standardized precipitations and temperatures.

9.21. Socio-environmental Resilience and Land Degradation: the contribution of a bio-regional approach

By Ilaria Zambon, Andrea Colantoni and Luca Salvati

Land degradation and desertification are complex socio-environmental processes that result from a complex interplay of biophysical and societal forces across spatial levels. Under adverse

biophysical conditions, resource-exploiting human activities that are driven by place- and time-specific combinations of societal forces trigger processes of land resource degradation (Blaikie and Brookfield 1987). Although land degradation is considered a reversible process, if its drivers are left unrestrained, land resources further decline leading to the irreparable condition of desertification, reducing ecosystem services. These processes also give rise to varied (and undesirable) socioeconomic influences, changing the socio-environmental welfare and hampering a potential sustainable development, especially in more vulnerable and affected areas (Blaikie and Brookfield 1987; Pili et al 2017; Delfanti et al 2017). In response to these phenomena, human involvement tries to address complex problems associated with land degradation and desertification, e.g. promoting human and environmental well-being in the affected regions. Formal and informal responses include prevention, mitigation, adaptation and restoration/rehabilitation, and incorporate different types of measures, e.g. management (sustainable land management practices and good practice), economic (resource pricing), communication and changes in land use (Briassoulis 2010). The main causes of soil degradation and increasing land sensitivity to desertification are mainly human-induced (Feoli et al., 2003) and more pronounced in areas with arid climate conditions, with water being the main factor restraining ecosystem performance, resilience and recovery (Simeonakis et al., 2007, Lavado Contador et al., 2009, Ferrara et al., 2014; Salvati et al., 2015).

Recent literature in socio-environmental systems encourages the adoption of Complex Adaptive Systems (CAS) models (Berkes and Folke 1998; Gunderson and Holling 2002; Glenn and Reynolds 2002). The CAS paradigm recognizes the inseparability and intertwined functioning of coupled socio-environmental systems, the nonlinear relationships among their components and the existence of positive and negative feedback mechanisms accounting for system's dynamics. Following the CAS model, the overarching goal for managing socio-environmental systems and planning interventions to alleviate their problems is preservation of the socio-ecological resilience characteristic of the socio-environmental system under study, i.e. the system's ecological resilience and community resilience simultaneously (Berkes and Folke 1998).

In the current literature on resilience, a traditional meaning of socioeconomic resilience is the ability of a regional economy to maintain a pre-existing state (typically assumed to be an equilibrium state) in the presence of some types of exogenous shocks. While, in the economic literature, resilience is linked with the extent to which an economy (which experienced a shock) is capable of returning to its preceding status and/or growth rate of output, employment, or population (Blanchard and Katz 1992; Rose and Liao 2005; Briguglio et al. 2006, Feyrer, Sacerdote, and Stern 2007). Another explanation could be the idea of path-dependence, or historical "lock-in" processes, based on the assumption that an economy has multiple equilibria, not all of which are efficient. This concept of regional economic resilience defines the ability of an economy to avoid becoming locked into such a low-level equilibrium or, if in one, to transition quickly to a "better" equilibrium.

Contrasting this quite linear vision, a long-term and holistic perspective would emphasize the structure of relationships among macroeconomic variables persisting over a long-term and regional economic growth, political and social institutions that condition this structure (Reich 1997). Therefore, an economy would be resilient to the extent that its social structure was stable or to the extent that it was able to make a rapid transition from one structure to another (Corona, 2015). In general, socioeconomic resilience can be defined as the ability of a region to recover positively from shocks to its economy that either throw it off its growth path or have the latent to throw it off its

growth path but do not actually do so. Economies that experience negative shocks may exhibit three different kinds of responses. Some of these may have returned to or surpassed their preceding growth within a relatively short temporal period; these regions might be called "economically resilient". While, some of them (called "shock-resistant") might not have been thrown off their development path at all. Finally, the remaining regions (called "non-resilient") may have been incapable to rebound and return to or surpass their previous path (Clark et al., 2018; Martin and Sunley, 2015; Pendall et al., 2010).

Among the several issues that hamper the effective implementation of mitigation policies in the field of land degradation, the following problems seem to be more prominent: (i) incomplete communication of the local level of governance with upper levels; (ii) a mismatch between scientific output and actual practical needs of affected regions; (iii) lack of context-specific solutions; (iv) weak scientific understanding of desertification as a process correlated with ecosystems services, human well-being and other global issues (e.g. climate change and biodiversity loss); (v) poor knowledge of the interactions between climate change adaptation, drought mitigation and restoration of degraded land in affected areas; (vi) weaknesses in development planning and programs; (vii) insufficient attention to the institutional factors and their relationships to sustainable land management; (viii) lack of vulnerability assessments in affected regions; (ix) weak support for effective policy making at the sub-global levels especially as regards synergies between desertification/land degradation action programs and measures stimulating mitigation and adaptation to climate change (Salvati et al., 2013).

The variety of environmental services provided is also mixed and constrained by the ecological and socioeconomic background together. Relevant environmental services include biodiversity conservation, watershed protection and water regulation, land degradation processes and mitigation of desertification risks (Basso et al. 2010). For these reasons, ecosystem complexity should be preserved through a correct management (MEA 2005) to increase the efficiency of services leading to socioeconomic and ecological cohesion (Figure 9.11).

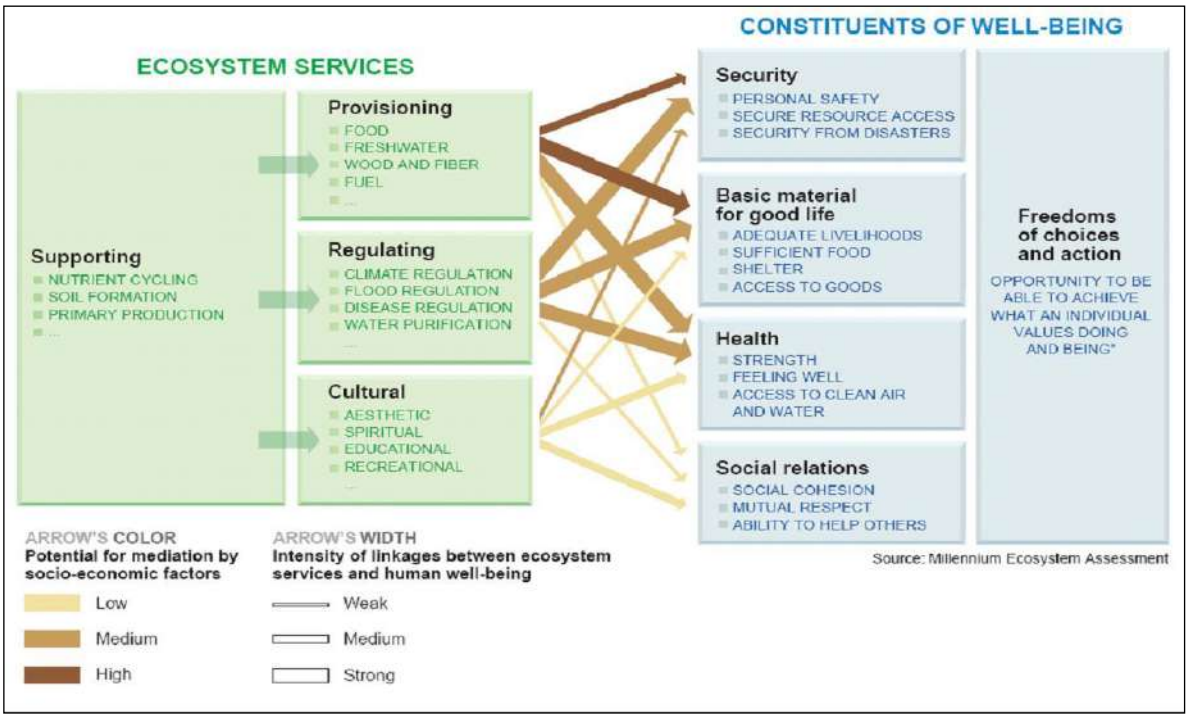

Figure 9.11. Linkages between Ecosystem Services and human Well-being (from MEA, 2005: p. 28).

High level of diversification in type and scale derives from different service typologies related to climate, land-use, social and economic assets. Regulation functions can be linked to (i) Climate and microclimate regulation, (ii) biogeochemical cycles (carbon and water), (iii) Drought mitigation, (iv) Soil erosion protection/prevention and land degradation and (v) desertification prevention (Petrosillo et al. 2010). Other support and production functions refer to biodiversity conservation, genetic resources, wildlife protection, water supply and quality, renewable energy, food and pasture (Colantoni et al., 2013a, b; Monarca et al., 2008, 2011). Ecosystem services can be also classified as function of their ambit of interest, such as Ecological, Social and Economic. that coexist in the same context although with different intensity. A key issue to preserve ecosystem complexity is represented by the way people extract goods, level of production, intended and unintended provision of services and by the level and quality of biodiversity (De Groot 2010). In fact, a simple change in land use may lead to a change in ecosystem service supply.

To better define the optimal landscape management approach to preserve and enhance ecosystem services, it is fundamental an evaluation process to understand and quantify how ecosystems provide services and valuate ecosystem services (De Groot 2010). So, the ecosystem services can be considered as a key issue in trade-off analysis and decision making within landscape planning and ecosystem management. Following the research by De Groot (2010) (Figure 9.12), the framework well explains the main relation between ecosystem and landscape services and the integrated assessment process to define landscape planning and ecosystem management to address policy and social questions, represented in the resulting steps: (i) understanding and measuring how ecosystems provide services; (ii) valuing ecosystem services; (iii) using ecosystem services in decision-making and trade-off analysis; (iv) using ecosystem services in management and planning; (v) funding sustainable use of ecosystem services.

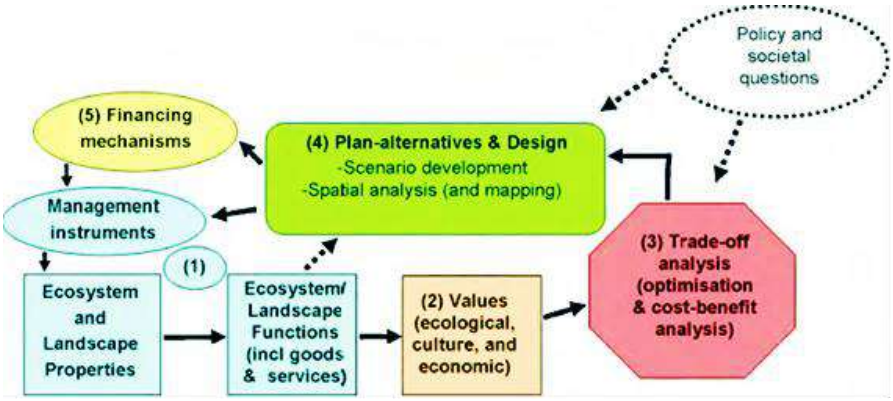

Figure 9.12. Framework for integrated assessment of ecosystem and landscape services (De Groot, 2010); (1)- (5) Themes addressed in the research program on Ecosystem and Landscape Services, Wageningen University (www.ecosystemservices.nl).

The aim of the present commentary is mixing the current frameworks of (i) bioregionalism planning, (ii) socio-ecological resilience and (iii) complex adapted systems to achieve a better comprehension of a complex and dynamic process such as land degradation in Mediterranean countries. The main conflict of sustainability is central mistake in the understanding of natural resources, particularly the supposition that ecosystem responses to human use are linear, predictable and controllable (Folke et al. 2002). In fact, in a complex world of rapid changes, the

resolution for sustainability lies in a new socio-scientific framework that sustains and enhances adaptive capacity. The key to resolution is resilience, the capacity to buffer change, and learning to develop under conditions of overexploitation and resource collapse (Frank, 2017). A sustainable future can be achieved through a bioregionalism approach, where people live actively in an ecologically defined and naturally delimited context (Thayer 2003; Silbernagel 2005). Resilient regions (Bristow 2010) and bioregions (Cato, 2012) can be considered such as intimately linked ideas, e.g. under the hypothesis that a bio-region may result from development of a resilient region (James and Cato, 2014a, b). In this regard, regional planning is requested to identify the symbolic importance of landscapes and protect meaningful places within it (Thayer 2003).

9.21.1. Complex systems and socio-ecological resilience: a bioregional approach

Bioregional planning assimilates social and biophysical information, concentrating on ecosystems as candidate units of analysis rather than political and administrative boundaries (Herring 1999). Bioregional approaches may interpret complexity and contemporary landscapes, basing on conflicts for urban-rural development, land-use and environmental matters (Donovan et al. 2009; Salvati et al., 2013, 2015). The identification of spatial influences can offer several options for territorial planning (Boothby 2000, Farina 2000). Geo-spatial technologies, e.g. GIS-based tools, can offer new opportunities to design influential approaches investigating such spatially-explicit connections among social and biophysical data that are essential to bioregional planning (Siniscalchi et al. 2006, Brown and Raymond 2007, Alessa et al. 2008).

Among the greatest environmental challenges, the ESA (Environmentally Sensitive Area) index estimates the level of land desertification which affects a specific area by means of four groups of indicators describing bio-physical processes and economical aspects (Kosmas et al., 2016, Basso et al., 2000). They provide information on vegetation, climate, soil and management by computing 15 different variables (Kosmas et al., 2000a; 2000b; 2003). It should be emphasized that the main goal of the ESA model was to define a reference framework to be used in analyzing various situations under the following operational constraints: (i) the system must be reasonably simple to establish, robust in operation, and widely applicable; (ii) the selection of the information layers is made, not only on the basis of their actual information content (i.e. their relationship with the phenomena under study), but also as a function of our ability to easily obtain and update the data; and (iii) the system must be adaptable and accommodate the development and refinement of the existing information content and the introduction/removal of information.

The methodology adopts a two-phases process (Kosmas et al., 2016; Basso et al., 2000). In the first step, the elementary data layers are combined to give four (quality) indicators for soil, climate, vegetation, and land management through computation of the geometric mean of the basic data layers. In the second step, the Environmental Sensitivity Area of each elementary unit is evaluated from the quality layers:

$$ESij = (Quality\_1ij * Quality\ \_2ij * Quality\ \_3ij * Quality\ \_4ij)\ (1/4)$$

where i, j are rows and columns of a single elementary pixel of each quality indicators and Quality_nij are the calculated values. Four quality indicators are usually calculated referring respectively to climate, soil, vegetation, and land management. A major concern is to define degradation phenomena considering the economic dimensions (in terms of land-use management) which characterizes it. Many studies highlighted that LD and desertification have measurable effects

on reducing economic resources (Tanrivermis 2003, Atis 2006, Hein 2007). Although limited quantitative data are available on the economic loss because of LD (Pagiola 1999), long-term economic and social planning is often hard to set up in environments where ecological conditions fluctuate (Bojo 1996).

Emphasis can be given to (i) the political, social, demographic, and production processes that reproduce and affect LD, (ii) its environmental consequences in the landscape, (iii) the implications on societies and economies themselves and (iv) the possible responses that societies are able to implement to contrast desertification (Briassoulis 2005) (Figure 9.13).

As concerns demographic dynamics, population increase may have several indirect consequences on LD (e.g. Salvati et al. 2008). Human pressure can be regarded owing to (i) practices such as relocation of people to the coastal border, due to tourism intensification, (ii) increasing population density in metropolitan regions, and (iii) concentration of industrial activities with the related impact on soil and water quality. Due to these processes, degradation of high-quality soils, increasing fire risk, loss of semi-natural vegetation, as well as salinization of groundwater are documented in urban areas and high-density coastal zones (Salvati et al. 2009; Biasi et al., 2015; Corona et al., 2014). Another key example of human-derived pressures on land is those caused by agricultural intensification. The intensification of agriculture usually means an increase in crop surface and greater technical skills (Salvati et al. 2007), that is a cause of soil degradation (e.g. Brouwer et al. 1991). Intensive farming practices, e.g. deep-water drainage, large-scale irrigation, heavy pesticide use, and multiple cropping are causing degradation of agricultural and semi-natural habitats across huge areas (Marathianou et al. 2000, Otto et al. 2007, Simeonakis et al. 2007; Cimini et al., 2013). Moreover, overstocking, over-cultivation, and deforestation play a major role in the process of LD in rural areas (Le Houerou 1993). These phenomena are themselves molded by socio-economic elements, such as the nature of property rights on land, more generally defined as 'environmental entitlements', the governing institutions, cultural and family traditions, as well as demographic dynamics (Wilson and Juntti, 2005).

Integrated and multi-disciplinary approaches represent an effective research strategy from the monitoring point of view (Wilson and Juntti 2005), including (i) the development of demographic, climate, and land use scenarios at different scales, (ii) the inclusion of these projections into quantitative methodologies analyzing land vulnerability to degradation over time, (iii) the analysis of the effects of past policies at both the regional and local levels, and (iii) the recognition of LD costs and benefits of mitigation measures at the same spatial/temporal scales, through adequate socio-economic models (Glenn et al. 1998).

LD and desertification can be regarded as socioeconomic problems mainly because the idea and practice of appropriation and use of land are socially constructed (Blaikie and Brookfield 1987). Consequently, considerations about soil productivity and land capacity, cultivations, land use, and sustainable development are the products of human-nature interaction processes (Mainguet 1994). Therefore, the themes of social and economic organization, integration, inequality, and political interventions, as well as their relationships with the production and reproduction of LD and desertification must be discussed in connection with the theoretical framework of sustainable development (Johnson and Lewis 2007).

9.21.2. Assessing resilience

Analyzing the socioeconomic framework, the recent concept of socioeconomic resilience is growing its importance although it has not been carefully defined or measured. Economically resilient and non-resilient economies can be identified by examining their economic performance over a temporal period using data on aggregate economic performance, while shock-resistant countries can be identified using data on industry performance or other information on non-industry shocks (Mancini et al., 2012). Criteria for an economic shock can be defined and measured in pre- and post-shock growth rates and levels of economic performance (Hill, et al, 2008). A region whose post-shock growth rate is at least as high as its pre-shock growth rate and that achieves its pre-shock level of economic performance within a definite temporal period can be called "resilient", while a region that experiences both a negative shock and without meeting these criteria can be defined "non-resilient" (Hill, et al, 2008).

Any spatial meaning of socioeconomic systems is to some degree subjective; these are open systems in which people, money, goods and services continually cross any boundary adopted. Further, if socioeconomic systems are defined in a spatial scale, interactions occur continually among all levels. The theoretical basis for socioeconomic resiliency rests on the concept of social well-being, which is defined as a composite of three factors: economic resiliency, social and cultural diversity, (population size, mix of skills) and civic infrastructure (McCool et al. 1997). An index of economic resiliency can be developed directly from measures of diversity in employment or income among economic sectors. Social and cultural diversity can be measured by using data on lifestyle diversity (Barkley et al. 1996). The socio-economic resiliency index is developed mixing three factors: economic resiliency, population density, and lifestyle diversity. Measures for both economic resiliency and lifestyle diversity are calculated using diversity indexes (Shannon and Weaver 1949).

Socioeconomic resilience is associated with actions undertaken by policy-makers and private agents which enable a region to withstand or recover from the negative effects of shocks (Briguglio et al. (2007). Actions which enable a region to better benefit from positive shocks are also considered to be conducive to economic resilience. Socio-economic resilience refers to the policy- induced ability of an economy to recover from or adjust to the negative impacts of adverse exogenous shocks and to benefit from positive shocks. The ability of an economy to recover from the effects of adverse shocks is associated with the flexibility of an economy, enabling it to bounce back after being adversely affected by a shock. Conversely, this ability will be improved when the economy owns discretionary policy tools which it can utilize to counter the effects of negative shocks. Ability to withstand shocks relates to the ability to absorb shocks, so that the end effect of a shock is neutered or rendered negligible. This kind of resilience happens when the economy has in place mechanisms to decrease the effects of shocks.

9.21.3. Components of socioeconomic resilience

An attempt to construct a comprehensive evaluation of socioeconomic resilience is reported as follows. Care is taken to base the selection on a set of desirable criteria related to appropriate coverage, simplicity and ease of comprehension, affordability, suitability for international comparisons and transparency (Briguglio et al., 2009; Naude et al., 2014). The compilation of the index encountered several problems regarding data collection, the most important of which were associated with shortage of data and non-homogenous definitions across countries. Resilience

indexes intend to measure the effect of shock-absorption or shock counteraction policies across countries. It is assumed that the variables that capture these effects are: macroeconomic stability; microeconomic market efficiency; good governance; and social development (Martin and Sunley, 2015; Modica and Reggiani, 2015; Mancini et al., 2012). A final composite index of resilience can be computed by taking a simple average of the four components just described.

Macroeconomic stability relates to the interaction among an economy's aggregate demand and aggregate supply (Naude et al., 2014). If combined expenditure in an economy moves in equilibrium with collective supply, the economy would be considered by internal balance, as demonstrated in a sustainable fiscal position, an unemployment rate, low price inflation, external balance (Briguglio et al., 2009). These can be all considered to be variables which are highly influenced by economic policy and which could act as good indicators of an economy's resilience in facing adverse shocks. The macroeconomic stability aspect of the resilience index proposed is constructed based on three variables: (i) the fiscal deficit to GDP ratio; the government budget position is suitable for inclusion in the resilience index because a healthy fiscal position would allow adjustments to taxation and expenditure policies in the face of adverse shocks; (ii) the sum of the unemployment and inflation rates. Those indicators are also considered to be suitable indicators of resilience since price inflation and unemployment are strongly influenced by other types of economic policy, including monetary and supply-side policies. They are associated with resilience because if an economy already has high levels of unemployment and inflation, it is likely that adverse shocks would impose significant costs on it; and (iii) the external debt to GDP ratio; the adequacy of external policy may be gauged through the inclusion of the external debt to GDP ratio. This is a good measure of resilience, because a country with a high level of external debt may find it more difficult to mobilize resources to offset the effects of external shocks.

Microeconomic Market Efficiency is constructed on the variables that composing the Economic Freedom of the World Index (Gwartney and Lawson, 2005), entitled "regulation of credit, labor and business" which is aimed at measuring the extent to which markets work competitively, freely and efficiently across countries (Naude et al., 2014). In the financial market, this index assesses the extent to which the banking industry is dominated by private firms; foreign banks are permitted to compete in the market; credit is supplied to the private sector; and controls on interest rates interfere with the market in credit. Interference relates to excessively high unemployment benefits, dismissal regulations, minimum wages impositions, centralized wage setting, extensions of union contracts to non-participating parties and conscription. All these are observed as probably precluding work effort, thus restraining the ability of a region to recover from adverse shocks. Bureaucratic control of business activities is also supposed to hinder market efficiency.

Good governance is indispensable for an economic organization to function correctly and to be resilient (Briguglio et al. 2009). Governance relates to issues e.g. rule of law and property rights in deriving an index of good governance. The Index covers five components: judicial independence; impartiality of courts; the protection of intellectual property rights; military interference in the rule of law; and political system and the integrity of the legal system. Social development is an additional component of economic resilience. Social development in a region can be measured in several ways such as connecting to income (e.g. proportion of the population living in poverty, the long-term unemployment rate).

9.21.4. Bioregional approaches and future progress

Bioregional approaches try to combine environmental and anthropological items present in the same landscape, providing a suitable biogeographical background to re-establish and preserve natural areas, sustainable practices and a truly sustainable development of a given region (Berg 2002; Eaton et al. 2007; Hutchinson 1996; Harris et al. 2016; Pili et al 2017; Duvernoy et al 2017; Marchetti et al., 2015). In this regard, agricultural areas, resilient cities or sustainable peri-urban landscapes have assumed a vital role in recent years (Colantoni et al. 2015; De Zeeuw et al. 2011; Olsson et al. 2016; Palazzo and Aristone 2017; Cecchini et al. 2018; Tomao et al., 2017). While, the resilience applied to the social-ecological systems can be considered as the capacity of a system to respond to disturbances and reorganize, undertaking changes to preserve their functions, structure and feedbacks do not exclude future development options. Each specific adaptability can define the capacity of the actors in an organization to achieve resilience. This perception is related to complex adaptive systems (CAS), which are usually characterized by self-organization without system-level intent (or centralized) control. Humans are unique in having the capacity for foresight and deliberate action, and self-organization in complex social-ecological systems is therefore somewhat different from that in ecological or physical systems (Westley 2002). Although the dynamics and direction of change in such systems are influenced by individuals and groups that have intent, the system does not, as in the case of a market. However, because human actions dominate social-ecological systems, the adaptability of such systems is mainly a function of the individuals and groups managing them. Their actions intentionally or unintentionally impact on resilience since their capacity to manage resilience determines whether they can avoid crossing into an unwelcome system regime or succeed in crossing into a desirable one (Berkes et al. 2003).

The resilience of a CAS at any one time is therefore complex and is likely to show change over both geographical space and through time (Salvati et al., 2015). Therefore, one of the aims for the ecosystem management is to encourage social and economic resiliency defined as the ability of human institutions to adapt to change (Haynes et al. 1996). These institutions include both communities and economies. A community is defined as a sense of place, organization, or structure (Galston and Baehler 1995). With the concept of socio-economic resiliency, such vision recognize that change is inherent in human systems. Social and economic factors are continuously changing - population grows, people migrate, social values evolve, and new technologies and knowledge are created (Delfanti et al 2017; Colantoni et al., 2013). In a study from Horne and Haynes (1999), the challenge is how to develop a measure of socioeconomic resiliency that is useful for understanding the extent to which changes in policies for land management may affect socioeconomic systems coincident with those lands (Quigley et al. 1996). The interest stems from a long-held concern about the relation between ecosystem management practices and the economic well-being of nearby residents (Mancini et al., 2012).

The relation among diversity and resiliency in socioeconomic schemes is comparable to that in the ecological literature (Moffat 1996): a system with higher diversity is less affected by alteration than a system with inferior diversity and consequently the previous has higher resilience (Elmqvist et al., 2003). Socioeconomic systems with high resiliency are defined as those that adapt rapidly as designated by recovering measures of socioeconomic well-being. People living in areas of high resiliency have a varied range of skills and admission to many employment opportunities (Meerow et al. 2016). Therefore, if specific firms or business sectors experience downturns, unemployment

rates rise only temporarily until displaced people find other employment. Systems with low resiliency have more persistent negative impacts, e.g. on unemployment rates. Having greater diversity (and higher resiliency) does not remove the option of wide variations for single economic entities or sectors (Mancini et al. 2012).

At the same time, it is important to mention that human societies have been built on biodiversity. Many activities indispensable for human subsistence lead to biodiversity loss, and this trend is likely to continue in the future. Biodiversity influences ecosystem services, that is, the benefits provided by ecosystems to humans (Díaz et al., 2006; Haines-Young and Potschin, 2010). Biodiversity has well-established or putative effects on several ecosystem services mediated by ecosystem processes. For instance, these services can be pollination, regulation of climatic conditions, the control of agricultural pests and diseases (Diaz et al., 2006). The links among biodiversity and ecosystem services have been gaining collective attention in the recent scientific literature (Díaz et al., 2006; Cardinale et al., 2012). The loss of biodiversity-dependent ecosystem services was expected to emphasize inequality and marginalization of the most vulnerable segments of society. Economic development, which does not consider effects on these ecosystem services, may decrease life quality of these vulnerable inhabitants.

9.22. Forest Expansion, Demographic Processes and the 'Modernization' Theory a Long-term Analysis in a European Country

By Valerio Moretti, Luca Salvati, Massimo Cecchini and Ilaria Zambon

This article investigates long-term forest decline and expansion with demographic processes observed in Italy, evidencing (more or less) coherent changes in the underlying ecological and socioeconomic context in the light of the 'modernization theory'. An exploratory data analysis of 58 indicators assessing 5 themes (environment, demography, education, trade, agriculture) was adopted to ascertain similarity patterns among indicators over a sufficiently long-time frame (1862-2009) and to identify time periods characterized by homogeneous conditions in different analysis' domains. Complementing indicators of forest expansion, changes in population structure and dynamics allow an empirical investigation of temporal coherence between demographic and forest transitions in Italy. The time window encompassing the two World Wars, approximately between 1931 and 1951, was identified as a turning point in the forest-socioeconomic system in Italy, indicating also two distinct groups of indicators that follow diverging (linear vs nonlinear) time trends. A secondary turning point was estimated at the beginning of the 1970s. Distinct temporal trends in the studied indicators (positive linear, negative linear and non-linear) were also identified using multivariate statistics. Taken together, these time intervals represent conditions of dynamic equilibrium between environmental and socioeconomic contexts, highlighting latent transitions in both population and environment conditions. This contribution provides an empirical understanding of political, economic, and socio-demographic forces associated with forest transition in advanced economies.

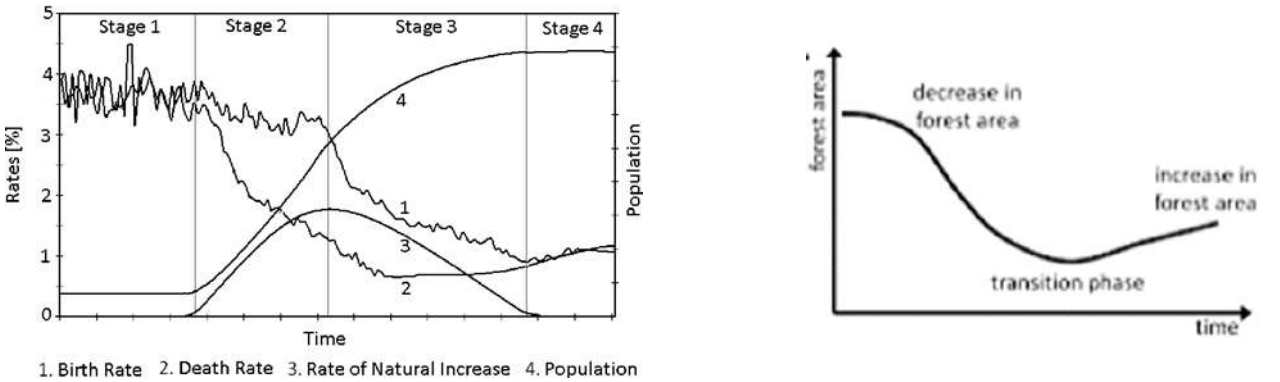

Figure 9.14. Schematic representations of demographic transition (left) and forest transition (right) in advanced economies.

9.23. Forest Fires, Demographic Dynamics and Socioeconomic Development in a Mediterranean Country, 1961-2017: an exploratory, time-series analysis

By Margherita Carlucci, Ilaria Zambon, Andrea Colantoni and Luca Salvati

Empirical studies investigating long-term trends in wildfires were relatively scarce in Europe. Temporal patterns of selected attributes describing forest fires in Italy were studied between 1961 and 2017 with the aim to identify homogeneous time periods with similar fire frequency and severity and correlate them with the background socioeconomic context. Three variables were specifically investigated: number of fire events, total burnt area and average fire size. These variables display a different behavior over time; number of fire events reached the maximum in the 1970s and the early 1980s, total burnt area was more constant with a moderate peak in the 1980s and average fire size decreased quite homogeneously from the peak observed in the 1960s and early 1970s. Number of fires and average fire size were both significantly influenced by the value of the same variable one year before. Multivariate analysis indicates a substantial difference in the socioeconomic profile by decade, evidencing a (more or less) rapid development in relation with the evolution of forest fires in Italy

9.24. Historical recurrence of fires in Italy

The historical recurrence of fires in the long term has been limitedly investigated. The present study explores 57 years of fires in Italy, exploring their average surface area burnt and the repetition of strong events. This long historical series was based on a set of 58 indicators describing economic, population, environmental and demographic issues. The database was correlated with fires at an annual time scale. The present study exposed that the recurrence of fires following an annual trend: a year determined by severe fires can suggest that the year after can be even more aggressive and intense. Fires do not have extended return times, but individual ones. This figure differs from other phenomena, e.g. climate regime, which follow biennial or triennial cycles. The long-term analysis also exhibited the differences among years over time: in the 1970s, fires were less intense, while they increased in intensity and severity in the 2010s. Therefore, fires increase in 3 characteristic dimensions (fire severity, intensity and frequency) over time in a socio-economic context that tends towards territorial disparities (or spatial polarization). Furthermore, the largest fires are in the most uninhabited and marginal territories; while, the most frequent fires, also due to human pressure, occur mainly near the most densely populated areas. Revealing a noticeable disparity along the

urban-rural gradient, a complex demographic and socio-economic system emerge where fires result to be over time larger and more unpredictable, making territories increasingly vulnerable.

9.25. Regional contexts, practices and projects for a bioregional recovery

A new spatial relationship among cities, territories and landscapes has emerged in the last half century, shading progressively the role of urban-rural gradients in regional studies. Addressing complex realities and increasingly debated regional issues, bio-regional approaches have acquired a strong interest in recent years. The present study focused on a case study in Greece (Thriasio Plain) representative of complex socio-ecological systems with a long industrial tradition and transforming relationships between urban and rural areas. Industrialization of the area and the related land-use changes were realized through a sequence of official revisions of zoning plans. Thriasio Plain has been characterized by spontaneous development of different activities with increasing impact on a fragile environment dominated by Mediterranean-type vegetation, poor soils and arid climate. By defining a consistent set of environmental indicators (Ecosystems and Air Quality Stress Indices), the present work aims at investigating recent dynamics typical of Mediterranean agro-urban outskirts, discussing suitable practices and projects for a bioregional recovery of degraded areas.

9.26. Urban Planning and Soil Quality: Investigating Latent Patterns in Rome and Barcelona

By Ilaria Zambon and Ilaria Tombolini

Recent urbanization led to economic changes with relevant impact on peri-urban soils, causing increased environmental concern especially in ecologically fragile districts. Spatial planning contributes to achieve sustainable land-use patterns and to drive optimal location of settlements and infrastructure. However, spatial planning has been sometimes unable to interpret and manage complex processes of metropolitan development, fueling unregulated and mainly dispersed urban expansion on land with less stringent building constraints. Considering Rome and Barcelona as emblematic cases of dispersed urbanization, this study investigates if their current planning system has been conceived in a strategic perspective oriented towards conservation and enhancement of soil quality. The highest values of soil and land quality were observed in urban districts, indicating processes of land take involving buildable, high-quality soils. Land devoted to natural and semi-natural land-use have a lower soil quality. Results of this investigation may inform regional planning and policies for the preservation of high-quality soils, especially under weak (or partial) regulatory constraints.

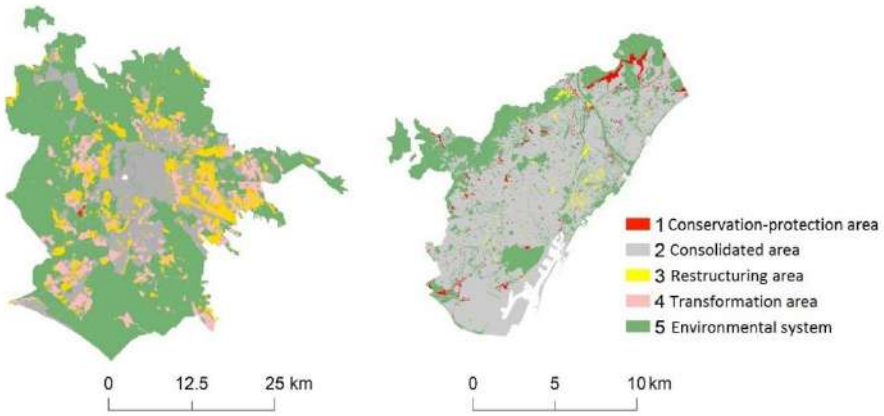

Figure 9.15. Rome and Barcelona following the elaborated categories from the strategic plans.

9.27. Unraveling the spatial distribution of Wildfires at the Valencian community (1993-2015). The role of road network as a key factor

By Ilaria Zambon, Artemi Cerdà, Luca Salvati and Pere Serra

Forest fires have commonly occurred during the dry and hot summers in the Iberian Peninsula. However, understanding the causes and their ignition points is essential to implement proper prevention policies and limit fires, at least of an anthropogenic nature. The aim of the present paper is to examine where forest fire mostly occurred in the territory of the Valencian Community. The analysis based at the municipal scale was carried out to observe which places were most affected, referring to a long-time period (1993-2015). Valencian Region shows a high variability in climatic conditions allowing to be assumed as a representative case of the Mediterranean Europe. Thanks to a spatial analysis, coincidence among fires, their ignition point and anthropic activities was verified. The spatial distribution of ignition points of fires may suggest useful information e.g. if they take place along the road network and at which hour fires are detected, contributing to find different causes of forest fires. The main hypothesis is if roads favor fires and increase the probability of fire. The spatial distribution of burnt areas along the streets roads gives rise to relevant implications, as a unique sort of landscape from which different impacts and consequences derive and which must be managed in the most appropriate way.

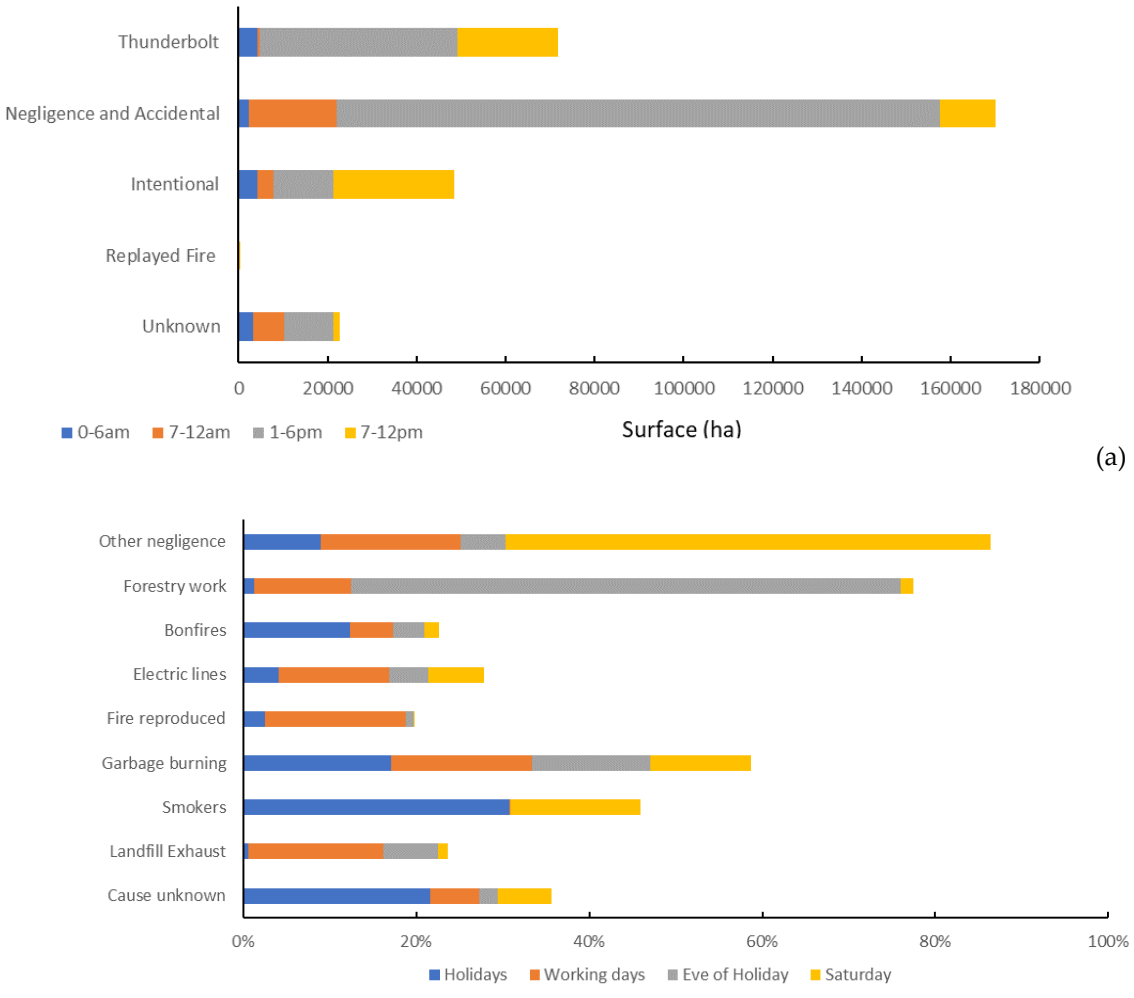

Figure 9.16. Hectares burnt for each type of cause triggered by fires and the related time of occurrence (a); and fires correlated to the kind of day and related causes (%) (b).

(a)

(b)

(c)

(d)

(e)

(f)

Figure 9.17. Forest fire in Carcaixent. June 2016. View in September 2016. Quick recovery thorough the spotters such as Quercus coccifera (a); Recently abandoned fields in densely populated areas results in fires (Carcaixent June 2016) (b and c); and Forest fire in Carcaixent, June 2016. One week after the fire (see Chamaerops humilis already sprouting (d); New plantations (citrus) and forest fires. The opening of new roads for the new plantations contributes to enhance fire risk (e); and Fire was a tool for farmers. Less prescribed fires results in higher biomass and higher fire risk (f).

9.28. Spatial and temporal evolution of the vineyard's in Valencia Region

By Ilaria Zambon, Artemi Cerdà and Luca Salvati

Vineyards have resumed their actual role as a cultural, economic and landscape resource in recent years and therefore the emerging concept of terroir is growing in the scientific literature. To properly understand the evolution of the terroir we need a research about the changes in space and time. The importance of exploring vineyard contexts implies different environmental repercussions, linked to land use changes and major soil degradation processes, such as soil erosion. Recent studies exposed that vine plantation cause serious environmental risks to soils. The purpose of this work is

to analyze how vineyard plots are distributed in the Valencian community, located in the Eastern area of the Iberian Peninsula, studying the final use of the product obtained, the type of vineyard and how long each vineyard has been settled over time. In this way, a picture of the current state of the wine-growing landscape in the Valencian community can be taken, investigating how interests and the wine market are changing the landscape itself. Vineyards have always been a characteristic element of the economy and landscape of the Valencian community. Knowing how long this crop has been present in the Valencian landscape, analyzing also different types of final use of wine, is useful for taking a picture of the existing vineyards, according to the year of their planting.

9.29. An assessment of the long-term pattern of air quality indices in a heavily industrialized and mixed land uses area. The case of Thriasio plain (Greece)

In elaboration.

9.30. Revolution 4.0: Industry vs Agriculture in a future development for SMEs

The present review retraces the steps of the industrial and agriculture revolution that have taken place up to the present day, giving ideas and considerations for the future. This paper analyses the specific challenges facing agriculture along the farming supply chain to permit the operative implementation of Industry 4.0 guidelines. The subsequent scientific value is an investigation of how Industry 4.0 approaches can be improved and be pertinent to the agricultural sector. However, industry is progressing at a much faster rate than agriculture. In fact, already today experts talk about Industry 5.0. On the other hand, the 4.0 revolution in agriculture is still limited to a few virtuous and innovative firms. For this reason, this work deals with how technological development affects different sectors (industry and agriculture) in different ways. In this innovative background, despite the advantages of industry or agriculture 4.0 for large enterprises, small and medium-sized enterprises (SMEs) often face complications in such innovative processes due to the continuous development in innovations and technologies. Policy makers should propose strategies, calls for proposals with aim of supporting SMEs to invest on these technologies and making them more competitive in the marketplace.

9.31. The role of grazing in the landscape interface between Mediterranean green areas and urban areas threatened by forest fires

By Ilaria Zambon, Artemi Cerdà, Pere Serra and Luca Salvati

The southern Europe is the most affected region by natural and anthropogenic wildfires in recent decades since continuous land-use transformations have reduced pasture activities and directed towards a rural abandonment. In these contexts, fires can spread more widely and aggressively, increasing the percentage of burnt areas and causing substantial economic and environmental damage. One of the most significant environmental matters in the Mediterranean basin is the increase of wildland-urban interfaces (WUIs) and how this tendency may affect the incidence of wildfires. Reduced grazing with land use changes and agricultural abandonment has led to a rise in forested areas with an accumulation and continuity of existing surface fuels for combustion. The present work focuses on the area of Mati, Rafina and Kineta in Attica region (Greece), near the Greek capital city Athens, where an intense and widespread fire occurred in the summer of 2018, causing severe damages, casualties and victims. The danger of this fire derives also from a sporadic territorial management, in which traditional agricultural and pastoral activities (mainly sheep and goats) have disappeared over time leaving immersed uncultivated and

abandoned areas. Such wild contexts therefore become part of a negligent landscape where highly combustible source or biomass grows. The final purpose of this work aims to explore and give more territorial awareness of the management of the landscape interface among abandoned areas and urban areas vulnerable to forest fires with a specific focus on fuel management in the wildland-urban interface, which embodies a substantial matter in terms of fire-risk supervision in the Mediterranean environments.

9.32. Using GIS Technologies for design Agro-energy districts

The current energy guidelines requested by the European Community encourage the use of renewable resources as an alternative to traditional fossil fuels. By supporting sustainable development, energy needs can be met through the transformation of agro-forestry biomass into biofuels. Therefore, the requirement to establish sustainable production and consumption chains at local level emerges. Accurate planning becomes crucial to ensure the establishment of agro-energy districts. Such process requires a careful analysis of potential energy resources that can be obtained in each territorial area. It should be remembered that the primary sector in Europe (and more specifically in Italy) has suffered a severe decline in recent decades, e.g. loss of employment and increase of abandoned rural areas. By re-establishing rural landscape and promoting multifunctional agriculture, agro-energy districts arise as competitive and sustainable realities for agricultural contexts.

The purpose of the present work is to highlight how GIS technologies are useful tools for identifying which rural areas, based on for example typical crops or contextual particularities, may become efficient agro-energy districts. Furthermore, by using GIS technologies the results highlighted a quantitative evaluation of biomass based on the agro-energy supply and demand of potential districts. Guaranteeing the correct knowledge and use of these tools, it is essential that economic, political and local actors are regarded as essential interacting components in innovative and efficient systems. In this sense, the present work also reflects on the educational impact of using GIS technologies as political decision-makers and planners must be able of enhancing local contexts with these tools with the aim of offering suitable opportunities and strategies for the sustainable development of agro-energy districts.

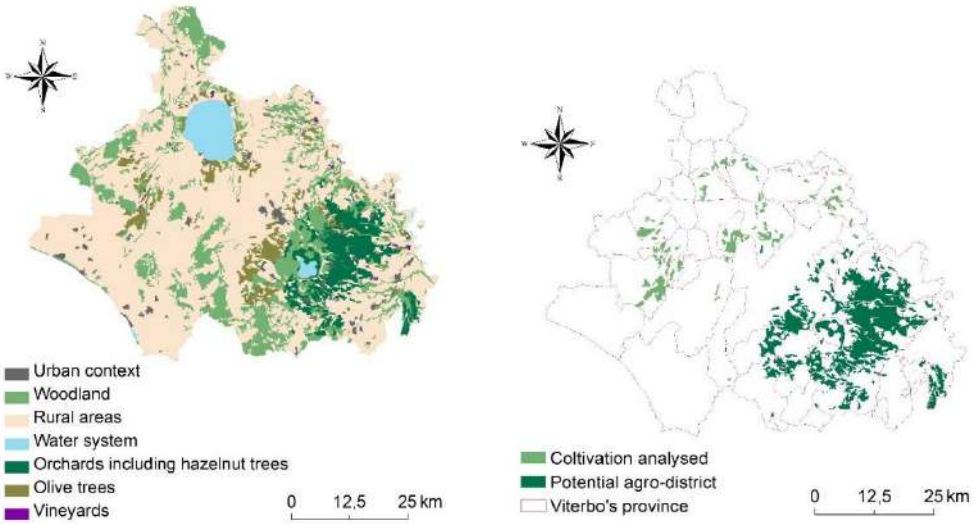

Figure 9.18. Land Corine Cover for each land-use class (left) and potential areas for the agro-energy district (right) for the province of Viterbo. Source: own elaboration.

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11. Conclusion

Several territorial contexts of Mediterranean Europe have considerably transformed over the last decades. These changes can be detected in demographic, socio-economic, environmental politic and landscape variations. Among urbanization processes, sprawl was the most invasive phenomenon due to its typical outcome of low-density outward urban expansion (Monclùs, 2000; Nel-lo, 2001; Muñoz, 2003; Catalàn et al., 2008). Sprawl processes occurred in both developed and emerging countries causing negative impact on socio-ecological systems (Bruegmann, 2005). Monitoring land-use changes is relevant since it offers useful information for urban planners and policy makers for the management of dispersive areas (Alphan, 2003; Anderlini, 2003). Analysing the different degrees of urban sprawl in European cities (Newman and Thornely 1996; Bonifazi and Heins, 2002; Brezger, 2006; Longhi and Musolesi, 2007; Turok and Mykhnenko, 2007). The work during the PhD period explored several Mediterranean contexts, such as Barcelona in Spain, Istanbul in Turkey, Rome and Naples in Italy and Athens (Greece).

Findings emphasized the importance of understanding urban changes as a requirement for the design of measures of sprawl. Comparative analysis of land-use and urbanization patterns and processes may spell out urban transformations and socioeconomic configurations. An integrated framework, involving quantitative analysis, evidenced the complexity in land-use transformations, proposing detailed solutions for sustainable land management concerning social cohesion, environmental sustainability and local competitiveness. In fact, sprawl outcomes are strongly related to socioeconomic matters at local scale and are inclined to several territorial factors acting at different scales. For instance, Barcelona presented a polycentric structure due to the consolidation of urban sub-centers scattered around the central city; the metropolitan area of Rome is more entropic and morphologically 'scattered', outlining the low-density settlement growth up to the 1980s (Krumholz, 1992; Salvati and De Rosa, 2014); while, the capital city Athens maintains its key role at the metropolitan scale, consolidating a typical mono-centric spatial system, in spite of specific low-density areas (Leontidou, 1990; Kourliouros, 1997; Couch et al., 2007).

However, not all the contexts analyzed have undergone dispersive processes of urbanization in recent decades. In fact, sprawl adapts itself to place-specific conditions in each context (Cavailhes et al., 2004; Caruso et al., 2007; Frenkel and Ashkenazi, 2008). For instance, the province of Viterbo has preserved over time its natural and agricultural system, regardless of whether the dispersive dynamics have also occurred (Di Felice et al., 2014). Socioeconomic factors have determined (and restricted) dispersive process in Tuscia, despite the inertia and inadequacy of the outdated planning tools. Tuscia represents one of the few Italian cases in which soil consumption is especially recorded in urban contexts with medium - high density (Munafò et al., 2015).

Exploring current urban contexts and territorial changes, new indicators were also formulated, such as the VHG index, which discriminate long-term vertical from horizontal urban expansion. The VHG index offered a conversant information, identifying spatial patterns of basic typologies of urban expansion in Greece. Distinct spatial patterns of building activity were distinguished in Greek municipalities, reflecting specific geographical gradients (e.g. urban-rural divides, coastal-inland polarization) and different replies to market stimuli and planning constraints (Pérez, 2010; Kourliouros et al., 2015; Papageorgiou, 2017). Intense vertical expansion coincides with a strong population growth in large urban areas (e.g. Athens); although, a moderate vertical expansion was

realized around medium-rank cities, along coastal areas and internal lowlands with small compact towns and tourism-specialized settlements. Significant differences were noted in the VHG index among Athens, the largest metropolitan area in Greece and the whole country, outlining how urban cycles were relatively heterogeneous over space, such as in other European countries (Salvati, 2016; Colantoni et al., 2016), explaining a joint examination of intensity and spatial direction of metropolitan development (Sarvestani et al., 2011; Biasi et al., 2015).

Also, Barcelona, Rome and Athens were investigated due to their scattered urban patterns as an outcome of divergent development processes (Di Feliciantonio and Salvati, 2014). Approaches based on indicators of land imperviousness provide relevant information on structural changes in metropolitan regions (Couch et al., 2007). Shannon diversity (H') and Pielou's evenness (J) indexes assessed the diversification in the degree of land imperviousness at the local scale. The highest values of these indexes were observed in central cities and polycentric sub-centers, where a greater heterogeneity in land-use is expected than rural areas since urban areas host dense population, upper economic functions and typical socio-spatial patterns. Central cities and sub-centers have comparable values of the Pielou's evenness, suggesting that entropy-based indicators can be more effective in the assessment of urban centrality than demographic or land-use indexes. This is especially true in spatially-complex socioeconomic contexts with both scattered or polycentric expansion (Salvati, 2014). The Pielou's evenness applied to land-use diversity permits a comparative investigation in the spatial structure of metropolitan regions, monitoring changes in the metropolitan hierarchy and classifying the most associated socioeconomic factors to entropic urban areas (Chen, 2008; Mohajeri et al., 2013). The distinct development paths, detected in the three southern European metropolitan areas, shaped mixed urban patterns with some similar features in terms of spatial structure and place-specific traits inclined to the differential localization of economic activities (Cavailhes et al., 2004; Caruso et al., 2007; Frenkel and Ashkenazi, 2008).

However, the findings obtained brought out the importance of a continuous updating of the processes of urbanization, with the aim of better managing urban containment (Salvati and Ferrara 2013), e.g. through urban redevelopment and the recovery of historic centers. Spatial planning tools ensure the containment of land consumption and the compatibility of development choices with the conservation and improvement of environmental and social quality. For instance, at the local scale, the joint analysis of aerial photographs and satellite images combined with field surveys, interviews with privileged subjects and bibliographic archives, land registries can allow an in-depth analysis, including for the development of environmental plans and territorial programs. Among the works proposed, an integrated research framework based on the use of high-resolution digital maps of planned and actual land-use was implemented with the aim to verify if deregulated urban expansion led to a progressive expansion of discontinuous settlements in Rome. Rome's expansion has reflected a combination of planning decisions and informal practices leading to interrelated (and sometimes uncontrolled) urban transformations (Maloutas 2004; Arbaci 2007; Arbaci and Malheiros 2010). This suggestion validates the outcomes detected in previous studies, examining spatial patterns of deregulated urban expansion in Rome as well as in other Mediterranean cities, e.g. in Athens (Costa et al., 1991; Archibugi 2004; Giannakourou 2005; Chorianopoulos et al., 2010). Furthermore, the increasing socioeconomic complexity and land fragmentation in metropolitan expansion arose from spatially-heterogeneous patterns of growth and ineffective land management and planning tools in Rome (Salvati and Gargiulo Morelli 2014).

Given the landscape complexity, the research work also proposed a novel approach to a joint structural and functional landscape analysis, introducing a new class of landscape metrics assessing basic features of patch perimeters. The results obtained were then match to other studies based on a classical landscape ecology approach (i.e. based on landscape metrics) with a functional analysis of land-use types assessing spatial neighboring patters. Therefore, a knowledge base was advanced through the integration of urban studies, landscape ecology and spatial science, contributing to renewed practices of sustainable management of fringe land in metropolitan regions. The metric's ensemble adopted was suitable to represent typical regional-scale landscape structures in a range of metropolitan configurations from compact and polycentric cities (e.g. Barcelona) to dispersed and mono-centric cities (e.g. Lisbon). Interestingly, perimeter metrics assumed different values for each investigated land-use class, with peculiar characteristics associated to each city. For instance, land-use types assessing residential, discontinuous urban patches were associated to particularly high values of perimeter metrics, indicating place-specific patch fragmentation, a spatially-associated distribution of land-use types and a landscape complexity profile specific for each examined region. Furthermore, substantial differences among cities emerged with a multivariate analysis, reflecting the range of morphological configurations (from compact mono-centric to dispersed polycentric) and suggesting that urban expansion goes together with manifold modifications in the surrounding non-urban land. The computational approach proposed mirrors latent changes in local socio-environmental structures (Salvati et al., 2013), making clear that scattered urban expansion can determine a hidden polarization in suburban areas with highly fragmented and more homogeneous landscapes (Carlucci et al., 2017; Cuadrado-Ciuraneta et al., 2017), correspondingly associated with mixed cropland and forest systems (Colantoni et al., 2015). Furthermore, place-specific contexts, influencing the landscape structure, were considered together with specific factors (e.g. elevation, patch size and shape, distance from the sea coast) for each studied patch. Spatial variability in the physical boundaries among patches (representing the nearest neighboring land-use spatial regime for each patch) is expected thoughtful of socio-spatial, demographic and economic evolutions that need an explicit investigation (Pili et al., 2017; Salvati and Gargiulo Morelli, 2014). In compact cities, a higher proportion of natural land surrounding urban settlements during compact growth was associated with larger urban patches, whereas cropland increased at lower elevation and dominated non-urban landscapes around fringe settlements. The role of factors (e.g. distance from inner cities in shaping the structure of suburban landscapes) is principally variable across cities, owing to the different spatial organization of each metropolitan region, and the opposite pattern was observed for urban patch size.

Always considering the most investigated cities (Athens, Rome, and Barcelona), the analysis of long-term urban transitions highlighted individual trajectories of metropolitan expansion. In the most recent decades, sub-centers were situated at increasing distances from central cities, following the progressive expansion of metropolitan regions with moderate population de-concentration (Longhi and Musolesi, 2007; Maloutas, 2007; Turok and Mykhnenko, 2007). More specifically, population sub-centers identified comprise (i) peri-urban municipalities around the city of Barcelona and some little towns located in rural areas; (ii) dispersed towns at variable distances (20-30 km) from the capital city, Rome; and (iii) fringe and peri-urban areas in flat contexts, 10-20 km outside the urban core of Athens. Findings may indicate a characteristic evolution path toward polycentric

development in the three cities, more evident in Barcelona and Rome while it is less deceptive in Athens.

Additionally, spatial dynamics are highly sensitive to economic conditions. For instance, the impact of 2007 recession have adversely affected the economic system and then new households' formation (Walford and Kurek, 2016), where socio-demographic polarization in urban and rural areas was exalted by the 2007 crisis (Salvati et al., 2016). Conversely, suburbanization assumed an important role in determining regional population dynamics in the pre-crisis period (Rontos et al., 2016). Thinking about the future of the region is fundamental. A hypothetic basis for realistic predictions of future urban growth in spatially-heterogeneous regions (Salvati and Carlucci, 2014), was built with indicators of land zoning derived from Municipal Master Plans, useful for (i) analyzing recent urbanization patterns and processes, (ii) formulating local-scale scenarios of urban growth and (iii) considering distinguished socioeconomic contexts underlying planning decisions. In the region of Catalonia, future urbanization will increasingly involve rural, medium-density areas, prefiguring urban expansion because of population growth, mixed densification or deconcentration of economic activities, and definite social profiles. Although the highest percentages of buildable land were found in peri-urban municipalities, the most accessible rural areas, especially flat districts along the Mediterranean Sea coast, will experience extensive urbanization (Smith, 2005). Although high percentages of buildable land were generally observed in municipalities with a demographic structure dominated by one-member households, the spatial distribution of buildable land in Catalonia's municipalities was associated neither with land rent nor with distance from the main urban centers. These evidences suggest how future urbanization processes will be partially decoupled from Catalonia's urban hierarchy, involving accessible rural areas progressively further away from central cities (Salvati and Carlucci, 2014).

All these urban changes directly affect the local landscape and specifically the natural, agricultural and forest contexts. For instance, the recent urban development in Attica region was analyzed since it has been characterized by episodes of illegal urbanization. Urban informality takes benefit from inefficient planning systems, transforming peri-urban landscapes into unplanned and spontaneous (low-density) urban development (Maloutas 2004; Arbaci 2007; Arbaci and Malheiros 2010). In fact, the Athens' metropolitan area was investigated since it is a typical mono-centric organization and more recent processes of urban sprawl into traditional rural areas (Leontidou, 1990; Kourliouros, 1997; Couch et al., 2007). By implementing a multivariate strategy to examine multi-domain indicators of urban expansion, clustering or scattering patterns in the spatial distribution of cropland were identified. From 1960 to 2010, a modest (and spatially-heterogeneous) increase in cropland occurred over time, mostly at the expenses of forest areas (Mather, 2004; Frenkel, 2004; Koutsias et al., 2010). Fringe landscapes turn out to be more heterogeneous and mixed, reflecting a hidden relationship among low-density settlements and medium-small farms specialized in tree and garden crops (Salvati et al., 2013). Cropland constituted a relevant part of fringe land: its transformations directly impacted on the structure of natural-based infrastructures surrounding Athens. The multivariate analysis evaluated where, when, and how increasing complexity occurred in Athens' landscape. Fundamentally, the distance from the city of Athens remained one of the most pertinent predictors of the spatial distribution of cropland. Furthermore, the Athens metropolitan region resulted to be sensitive to environmental degradation (Salvati and Zitti, 2005) owing to the progressive urbanization of rural fringe (Salvati et al., 2012). So, multi-scalar

sustainable land management policies resulted necessary (Monarca et al., 2012; Monarca et al., 2011; Monarca et al., 2008; Pari et al., 2015; Carlini et al., 2017) in reducing the impact of urban sprawl on cropland (Colantoni et al., 2016; Salvati et al., 2008). Simultaneously, a more effective protection of traditional agriculture is mandatory, particularly for rural and remote districts (Ceccarelli et al., 2014).

In the face of these landscape changes, society and the economic system also vary in peri-urban contexts. Analyzing long-term dynamics of peri-urban agriculture and urban expansion in other study case, such as Toulouse, reflect both the consequence of urbanization on farms and the ability among farmers to manage with manifold adaptations to urban/peri-urban environments characterized by characteristic conflicts in land-use, land consumption, farmer entrepreneurialism and the concentration of holdings among non-farmers. The analysis integrates long-term, general trends in farming systems at the regional scale with place-specific dynamics more likely driven by the characteristic local context, strongly inclined to the dispersed expansion of Toulouse's urban fabric. Within this background, divergent indications arise from the qualitative analysis elaborated. Farmers interviewed mainly cultivate the most common crops. While, quantitative results confirmed the well-known conflict among urban development and agriculture, demonstrating also a high level of diversity in crop productions at the metropolitan spatial scale. Qualitative data, focusing on the predominant production of arable crops, emphasized the growing scale at which farmers develop their strategies of change, to expand their farm or their contracting activity as agricultural contractors. The few cases of diversification towards other productions, short food chain and recreational activity are indications of probable linkages among the considered conventional farming and the urban food system.

Offering new insights in sustainable land management strategies adapted to evolving metropolitan contexts, also the identification of processes of urban growth and changes in peri-urban landscapes dominated by specific crop cultivated, e.g. olive groves, can be useful in a defined spatial area. Following some results, olive trees expanded into fringe land of Athens' metropolitan area, preserving significant crop surfaces in more rural areas. Exactly, areas destined for olive crops reduced only in the most compact part of the greater Athens area, revealing a comparable tendency with other rural productions, where the loss of agricultural areas was driven by dense urbanization. In respect to other cropping systems, olive groves conserved in some peri-urban districts lead to a durable presence of natural landscapes in metropolitan contexts (Recanatesi et al., 2016). This phenomenon is mainly relevant in the eastern district of Attica, where the most intense processes of suburbanization have occurred. Furthermore, finding were in line with the most recent features of a typical post-productive phase of the European agricultural sector (Kristensen et al. ,2001), reflecting the recently introduced greening measures in the EU agricultural legislation, the greater awareness of the environmental impact of agriculture and a progressive increase in the number of part-time and hobby farmers with limited involvement in full-time agricultural activities, especially in metropolitan regions.

Always in Athens' metropolitan area, also fallow land dynamics were considered a useful indicator (i) to infer latent transformations in peri-urban landscapes and (ii) to propose strategies for promoting peri-urban agriculture and/or preserving relict cropping systems. Results suggested that both increasing tree crops and decreasing fallow land are indirectly connected to low-density urban

processes. At least for the last decade, an increasing polarization emerged in (i) economically-marginal rural land, with high rate of cropland abandonment, forestation, moderate human pressure, and urban sprawl, and in (ii) highly-productive agricultural districts, with decreasing proportion of fallow land, stable cropland, a more intense conversion to tree crop systems, and reduced land speculation for alternative uses of land-including conversion to urban destinations. Findings were in line with general transformations of rural landscapes observed in Attica but also in other Mediterranean urban regions (Gutierrez et al., 2009; Kizos, 2010; Loumou et al., 2003), including local-scale processes of agricultural intensification or extensivation. Understanding how the rural landscape cohabits with other land-use along urban fringes is essential since multifaceted processes have been observed over the last decades, leading urban and rural elements to coexist (Moissidis and Duquenne, 1997). In these regards, fallow land can be a sensitive landscape component to the local economy, society and environment.

The research study also offered another approach aimed at verifying if landscape composition, structure and diversity significantly changed along the urban-rural gradient in Greece. Findings underlined that, where fallow land is less present, there are wrecks and critically connected agricultural systems; while, with more land available for production, a greater rural intensification can be conducted to a greater fallow land. Additionally, fallow land can designate soil fluctuations that are not closely linked to agricultural use. For instance, greater fallow land near Athens can reveal an abandonment of agricultural land for speculative purposes. Specially, outcomes revealed that since 1970-79, especially in Attica and Peloponnese, fallow land was more concentrated. In the central northern area, fallow land areas exhibited a more homogeneous distribution, associated to the most intensive cultivation models (e.g. horticultural crops) and viticulture, which is an important source of income for farmers (Ragkos et al., 2015; Ioannides et al., 2001). Then, olive landscapes recorded a strong rural diversification, also correlated to their strong inclination to rapid changes. In the last period, the intensive agricultural systems have stimulated urbanization processes, linked to the tourism sector e.g. in Crete, leading to a contraction of agricultural landscapes. Consequently, in recent years there has been less diversification in this case.

Based on these results, the usefulness of comparative and multi-temporal approaches to landscape changes in complex regions emerged (Alphan, 2003; Marull and Mallarach, 2005; Paul and Tonts, 2005; Cuadrado-Ciuraneta et al., 2017). Some outcomes suggested the protection of a spatially balanced landscape diversity structure along the urban-rural gradient as a key goal for strategies and suitable policies designed to sustainable land management, avoiding (i) speculative actions linked to urbanization processes, (ii) ineffective environmental policies on quality and diversity of peri-urban landscapes, (iii) soil sealing and degradation (Couch et al., 2007).

Providing a wide-ranging summary of the rapidly-evolving socioeconomic conditions over different time intervals (Milbourne, 2007), new notions, such as 'rurality' and 'rural development', should be discussed within a new agenda bearing in mind together urban processes e.g. sprawl and counter-urbanization (Benson and O'reilly, 2009). Furthermore, environmental threats and soil consumption should be included as relevant concepts in policy agenda. Defining adequate methodologies to assess the relationship among environmental, economic and social factors is predictable as a difficult mission due to the heterogeneity of cause-effects relationships, e.g. linkage among land degradation and anthropologic activities (Rubio and Bochet 1998; Kosmas et al. 2003).

With the purpose of sustainable growth, effective measures should be designed against environment threats, e.g. desertification. Strategies aimed at reducing environmental disparities, particularly in rural/marginal areas, are decisive to attain a sustainable development which preserves high environmental quality and mitigates potential land degradation (Wilson and Juntti 2005; Salvati and Zitti 2007). The linkage of land degradation with demographic, urban-rural and economic dynamics should unquestionably face in the design of an all-inclusive policy framework on the way to sustainable development. However, this objective is challenging when comparing different case studies. Considering 155 metropolitan regions selected in six European areas, the diversity emerged due to different history, tradition and consistency of the territorial management tools. The evolving planning culture influenced urban trends among European regions (Hall and Hay, 1980; Di Feliciantonio and Salvati, 2015). However, the outcomes of spatial planning policies are not simple to evaluate (Van Der Burg and Dieleman, 2004). Geo-spatial databases assessing land-use change over long-time periods deliver the essential information to assess how land consumption (i) influences urban structure and European peri-urban landscapes (and vice versa) and (ii) is intimately related to the (evolving) socioeconomic context at local scale (Munafò et al., 2010). Cities in United Kingdom, Central and Northern European countries challenged with a low rate of land consumption during 2006-2012. Although, being occasionally characterized by a sprawled urban structure, some of these cities have adopted effective control mechanisms as a reply to uncontained urbanization and residential sprawl (Halleux et al., 2012). More effective policies at different scale resulted increasingly required to diminish land consumption in growing (and even shrinking) regions. Though urban containment strategies are recognized planning tools for handling urban sprawl, their indirect impact on land consumption should be better examined (Gennaio et al., 2009).

Focusing on land quality, sustainable development and environmental degradation in agricultural districts, the level of land sensitivity to degradation resulted influenced by spatial heterogeneity in the environmental conditions at the base of land degradation. Mediterranean rural areas are considered as increasingly exposed to desertification risk, due to joint action of climate aridity and socioeconomic pressures (Lorent et al., 2008; Mendelsohn and Dinar, 2003; Olesen and Bindi, 2002; Salvati and Zitti, 2009). Agricultural districts with spatially-homogeneous environmental situations brought about to be more visible to land degradation in recent decades in respect to the time-period immediately following the World War II. Diversification in the spatial distribution of the ESAI has been connected to specific territorial contexts characterized by a high degree of land sensitivity. Cropland confirmed to be mainly prone to environmental conditions leading to land degradation when the spatial structure of agro-forest districts (e.g. crop mosaic and landscape fragmentation) has been compromised (Colantoni et al., 2015). Human-driven land degradation has been detected in both economically-marginal rural areas of southern Italy and affluent districts of northern Italy with soil and climate conditions getting worse in the last decades (Salvati and Carlucci, 2013). Despite Southern Italy is widely recognized as a risky area (Salvati and Bajocco, 2011), land degradation sensitivity was advancing rapidly also in central and northern Italy. The spatial distribution of rural districts sensitive to land degradation was fragmented and heterogeneous (Salvati and Carlucci, 2013). According to the results obtained, soil and vegetation are the most components associated to spatially-heterogeneous conditions predisposing land to high sensitivity to degradation. Imbalanced environmental conditions in terms of natural capital require measures diminishing soil degradation and protecting natural vegetation with the final objective to

recover components' balance and spatial heterogeneity in land degradation (Hamdouch and Zuindeau, 2010). Together with soil and vegetation, climate quality represents a component strongly connected to imbalanced ecological conditions possibly leading to land degradation (Lavado Contador et al., 2009; Montanarella, 2007; Sivakumar, 2007). Local climate regimes are only indirectly influenced by environmental policies, suggesting implementing strategies for the mitigation of land degradation (Hermann and Hutchinson, 2005).

Nevertheless, the issue of land degradation, particularly linked to the loss of highly quality soils, is of great concern to the European contexts, especially in the Mediterranean basin. Considering 66 metropolitan areas in Portugal, Spain, France, Italy and Greece, a generalized loss of high-quality soils in peri-urban areas was detected. Though, this pattern is spatially heterogeneous since high-quality soils were consumed principally in small-size metropolitan regions with medium-low population density and a modest level of per-capita income (Salvati et al., 2014). While expanding rapidly, large cities with highly diversified landscapes are consuming low-quality agricultural and forest soils. High-quality agricultural soils, less fragmented landscapes, growing incomes and a considerable proportion of construction sites and land without current use are characterized in socioeconomic contexts with large consumption of high-quality soils. Results were in partial agreement with previous studies focusing on landscape transformations driven by urban expansion (Verburg et al., 2008). Metropolitan regions with low-quality non-urban land exposed to desertification risk expanded systematically on soils with below-average quality in respect with neighboring soils (Barbero Sierra et al., 2013). Comparable outlines of soil consumption were detected for compact and dispersed settlements. Nevertheless, mixed settlements are related to a higher rate of high-quality soil consumption than both compact and dispersed settlements. Reflecting on urban sustainability, findings specified that land-saving cities should be recognized according to a (desirably low) rate of land take with preference for low-quality soils. Land protection regimes should be enhanced in high-quality open areas, close to forests and mixed cropland, intended as suitable sites for discontinuous urban expansion (Salvati et al., 2015). Integrated strategies for sustainable development are progressively compulsory to consider social cohesion, economic growth and environmental quality as joint policy targets in areas with low-quality soils (Ferrara et al., 2014). Regional plans merging environmental and socioeconomic measures may limit consumption of high-quality soils, in turn reducing the negative impact of sprawl.

Finally, soil degradation and erosion processes such as emerging environmental issues also include unpredictable events, such as wildfires. The latter were a studied in Viterbo and during the research period in Valencia, expressing how the need for appropriate approaches, strategies and plans can be useful to prevent fires, manage sensitive areas and potentially avoid the loss of valuable land.

To make it easier to promote more sustainable territorial contexts, new technologies can be useful. By following recent reports on smart contexts, it is possible to identify which strategies to adopt in each background under analysis. The formation of smart cities realities strongly on the local configuration. Technological innovation, active society and dynamic economy, synergies that increase progress, citizens adapting sustainable behaviors all prerequisites that increase the 'smart' degree. In central and southern Italy, small and medium cities usually occupy the last positions of the report rankings of smart cities. The need to define "smart" tools, strategies and suitable policies

is essential familiarizing with new technology and offering innovative job opportunities. From this background, the option of establishing agro-energetic districts represent a real chance for southern and central realities, which are rich of natural and agricultural resources, with the determination of strengthening their socio-economic structures with more technological innovation and environmental quality, reducing potential waste. Furthermore, the presence of an active socioeconomic system conducted to more innovative territorial context. Results confirmed that the smartest contexts are those that are positively associated to high (youth) employment rate, advanced educational qualifications, high per-capita income, heterogeneous society (e.g. foreigners, mixed couples) and high mobility at the provincial scale. Though, low degree of education, low degree of job skill and spatial stasis do not emerge in the virtuous contexts.

Using GIS technologies made it possible to recognize which realities can offer new development opportunities e.g. in the primary sector or in peri-urban landscape. For instance, the possibility of installing photovoltaic panels into greenhouses plants used for continuous crops. However, the research work also revealed national shortcomings since a lack of spatial database (e.g. greenhouse or photovoltaic systems), approaches and methodological tools designed at developing research and innovation solutions was detected in Italy. Among the main prospects, the detection and localization of greenhouse plants can help policy-makers and other stakeholders to take the appropriate decisions on the territorial and resource management (e.g. energy) (Carvajal et al., 2006). Continuous monitoring must be guaranteed through GIS programs by collecting, processing, retrieving and displaying spatial data (Rogge et al., 2008). The existing studies emphasize that GIS elaboration can support policy-makers in addressing key issues (Peccol et al., 1996) and taking effective decision-support systems that deal with the territorial planning (Bryan, 2003).

In agricultural system, the use of network RTK in GNSS was applied to hilly areas following an approach based on criteria of precision farming. The investigation for the usage of permanent stations achieved some significant findings, as (i) the correction sent by permanent stations via the Network RTK to the GNSS system, about the vehicle in motion, was uniform and (ii) the degree of precision varied relating to the satellite constellation, visible during the usage and according to GPRS coverage, with which the system connected firstly to the network and then to the server.

New technologies also help to identify where the major critical issues persist, as in the study carried out for job accidents in the primary sector. The study was useful for several reasons. Firstly, it exposed that the number of injuries reduced over time, likely influenced by a thorough supply of educational courses dealing with safety at work. Secondly, the most critical months are March, June, July, September and October, which likely reflect the most dangerous agricultural practices. Thirdly, a lot of injuries occurred in central and northern Italy, with a specific socio-demographic profile (males aged 35-60 years old). Agricultural workplace accidents interested mainly older people, exposing that increased age of the workers can cause during their performance and their attention at work (Stoneman et al., 2014).

The main issue of the research work emerges with the results offered on the study of agro-energy districts. Agro-energy districts have been examined in different Italian contexts, showing their local opportunities but also their implementation limits. In Sicily, GIS processing let to recognize the most appropriate areas for the cultivation (and collection) of hazelnuts, since this kind of agriculture is not recommended on the steep slopes and can cause invasive environmental processes e.g. soil

erosion (Ozturk et al., 2007; Tanik et al., 2008). Furthermore, one of the limitations that emerged in this study was the lack of useful databases to study and analyze the case study, specifically related to local land-use. The analysis focused also in e.g. topography, morphology, land-use changes and slopes, which are useful to then reflect on which agrarian and mechanization systems apply in order to avoid possible accidents at work, especially during hazelnut harvesting.

In prospective of an innovative agro-forestry supply chain for residual biomass, a physicochemical characterization of biochar from olive and hazelnut pellets was offered. The two-biochar analyzed show good physicochemical properties, which makes them suitable for agricultural applications. Biochar fuel commands a high-value application, contributing to numerous benefits and to develop the biomass utilization efficiency (Anupam et al., 2016; Liu et al., 2013). The added value of biochar is also linked to other issues, e.g. involving agricultural and environmental sustainability (Lehmann and Stephen, 2009); as a soil amendment, biochar can improve soil health and increase agricultural productivity with further environmental benefits related to global warming mitigation (Reza et al., 2014; Hill et al., 2006; Chandra et al., 2012; Kim et al., 2015; Civitarese et al., 2015).

An innovative framework based on the design of a complete plant for the energy production with a net power output of 4 MWe, located in an industrial site of the municipality of Rieti (Italy), was proposed. Results revealed that the studied plant can be sustainable over time, owing to the relevant incidence of forest biomass in the province of Rieti, which emerged thanks to territorial analysis. The transportation costs were not so excessive due to the closeness of the location of the proposed plant to biomass source regions. The energy plant considered can benefit from different waste material, e.g., poplar cultivation and beech trees. Thus, it also allows the energy plant to continuously operate, also ensuring that its operators unceasingly work permitting continuous job conditions (Marucci et al., 2013; Colantoni et al., 2013). The impact of the proposed plant was measured exclusively on atmospheric emissions, as the plant is placed in industrial areas without landscape or naturalistic value (Colantoni et al., 2015). From the environmental point of view, the plant is fully consistent with local and national laws, since emissions are largely under legal thresholds thanks to the use of forest biomass as energy fuel, the enhanced combustion capacity of modern boilers, and the gas treatment that it envisages. An economic and financial examination to find out the real feasibility of the plant was carried out, envisaging a return on investment of 8%. Regarding the purchase costs of the different types of biomass, prices appeared to be relatively stable.

Another representative biogas plant of small size (250 kWel) was proposed in a local farm. However, results revealed that small biogas plants are still an attractive investment (Karellas et al., 2010), despite the reduction the incentive base rate has suffered over time (Agostini et al., 2016). Nevertheless, small plants fed with by-products or agro-industrial waste resulted to: (i) recovery and reuse production waste; (ii) enhance short chain; and (iii) promote local sustainable development (Bond and Templeton, 2011).

Agro-energy districts were not only intended as an area dedicated to agriculture, but also with the presence of greenhouse plants and the possibility of applying photovoltaic systems. However, the study of this subject started from the evidence that soil has become increasingly impermeable in recent decades, due to convenient incentives that have sealed the Italian rural soils in favor of ground

photovoltaic fields, initially considered sustainable from every environmental standpoint. Results specified that the recent expansion of solar systems in Italy was mainly concentrated on both traditional and intensive agricultural districts in flat and hilly areas with optimal or sub-optimal conditions for cropping. Their spreading derived also from heterogeneous (and possibly poorly effective) planning measures regulating the spatial development of rural areas traditionally devoted to intensive agriculture (Ceccarelli et al., 2014). From this highlight, greenhouse systems represented a conceivable structure in which to install photovoltaic systems in agricultural contexts. Therefore, the preference is for photovoltaic systems installed on the roof of constructions than those on the ground. However, the project to install photovoltaic roof was tough, due to the curved shape of the tunnel greenhouse studied in Viterbo, which do not lend to accommodate easily photovoltaic panels on the coverage. Shading is one of the major restrictions for the photovoltaic installation on the roofs of greenhouses (Tudisca et al., 2013; Pérez-Alonso et al., 2012). The annual shading differences resulted a suitable indicator for choosing the greatest mixture of photovoltaic panels and the existing crops, with the purpose to optimize both energetic and production activities (Lopez-Marin et al., 2012; Urena-Sanchez et al., 2012). The study offered transparent and flexible photovoltaic panels installed on the roof, bringing out an added value to the present research. Assessing the effect on crops of the tendency of the shading scores under the string was determined for the duration of the day for one year. The constant trend of shading on crops made it possible both (i) to select the sequence of the crops and (ii) also to remove them, with simple handling of the panels of the system, when the solar radiation fell under a definite threshold (e.g. cloudy days). The shading uniformity was concerned as a closing question addressed in the research since it has significantly increased during the colder months as it depends on both the height of the sun and the angle of the photovoltaic panels, which varies along the tunnel section.

A similar application was carried out also in Sanremo, detecting the shading effects of photovoltaic system on some flowers growth. The opportunity to productive recovery of existing greenhouses is a complex aspect, which provides an interdisciplinary effort. Results brought out that a quantitative and qualitative reduction of the crop production did not emerge. The analysis of the brightness data, with reference to the parameters of illuminance (lux accidents), global radiation and PAR (Photosynthetically Active Radiation), provided values that were statistically higher in the sector, without being influenced by photovoltaic panels, in a greater extent for lux accidents (with two times higher values) and lesser for global radiation (30%) and PAR (20%). These conditions allowed plants to grow and reach anthesis (except for the iberis, not bloomed in both thesis) without great alterations from the standpoint of the marketability of the commercial product. For the cyclamen, some slight differences were recorded due to an increase of the surface of the light capitation with a greater development of its vegetative part in the shaded area and fewer blossoms, but without affecting its commercial quality. Indeed, it is well known that light profoundly affects the plant life. The most important reactions of plants to optical radiation are (i) photosynthesis, (i) phototropism and (iii) photo-morphogenesis. The green radiations exposed significant to yield the greatest productivity and efficiency in greenhouses grown plants, although differences could be scored according to the species. In the experiment, plants grown under photovoltaic conditions were always subjected to a lower PAR compared to the control, and the values allowed an efficient photosynthesis process being the first three weeks of cultivation more favorable.

The research study ends with a context dedicated to vineyards. Especially, the research work focuses on the three concepts of sustainability, which should also include a fourth component: energy. In this sense, also through energy, it is possible to create a system (or agricultural districts as studied) based on a circular economy that respects the environment, offers work to the local society and stimulates competitive economic processes, recycling everything that is produced avoiding waste. Given the prestige of the growing Italian wine sector, the integration of an agro-energy district in the wine sector considered is feasible even if it depends on the variability in the production of residues which is linked to many factors, e.g. structure, geographical location and position of the vineyard (Francescato et al., 2007). From the economic investigation, different scenarios can be depicted. Though, the reuse of rural residues brings about the cheapest strategy for a local sustainable development as wood chips from wine shoots ranges from 46 to 87 € / tons. By integrating the four dimensions (energy, economy, society and environment) that can lead to greater sustainable development, agro-energy districts applied to realities e.g. the wine-producing ones may be a developing phenomenon that provides a new scenario of rural areas in the evolution towards a sustainable (energy) future. But the present research suggests that further development of policies, strategies and network of local actors must be structured and well managed is indispensable to accomplish long-term positive consequences.

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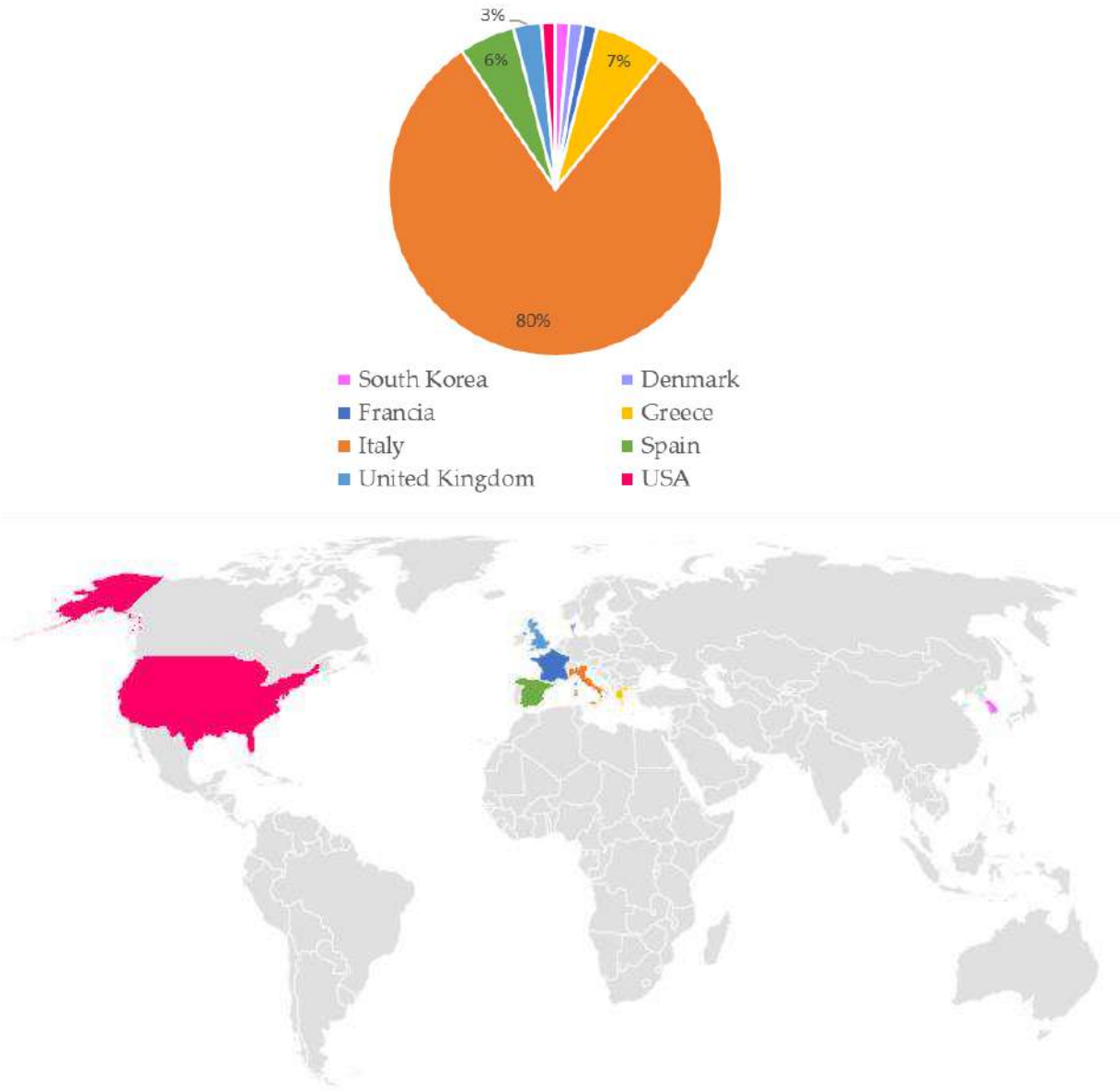

Figure. Global partnership in articles and number of authors following their country's institution.

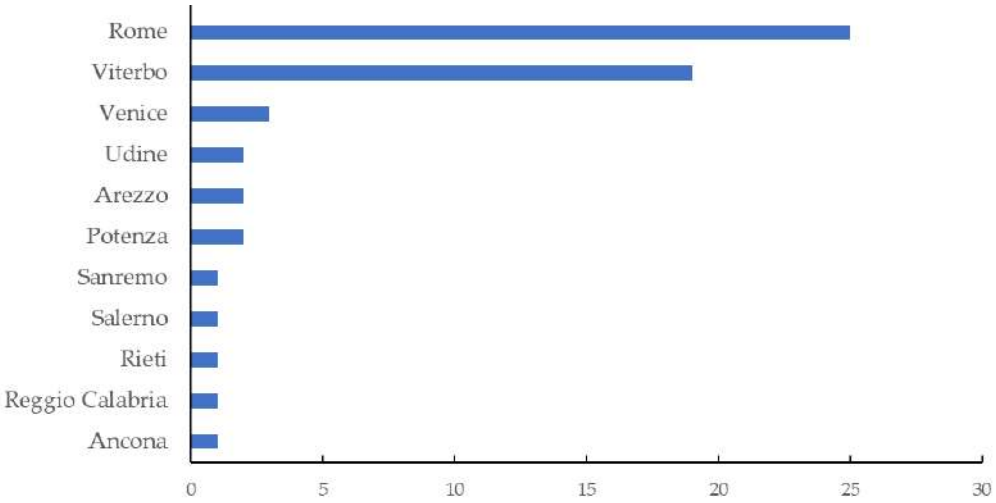

Figure. Number of Italian authors following the city in their affiliation.